

IUE Final Archive Calibration: Camera Repeatability Analysis

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Introduction

Camera repeatability (*a.k.a.* reproducibility) analysis has been performed on low-dispersion data taken with the *International Ultraviolet Explorer (IUE)* and reprocessed with the New Spectral Image Processing System (NEWSIPS). Camera repeatability is defined as the measure of the error in detected flux in multiple observations of the same object taken under identical conditions. A thorough understanding of how the *IUE* cameras behave from image to image is important when performing comparisons of spectral data and when looking for variability in an object. One must take into account the repeatability of a camera in order to ascertain the credibility of variations in spectral lines or continuum levels. That is, if the variation of a measured feature is less than the measured repeatability error, the results are meaningless. As a result of this concern, repeatability measurements have been computed in 25Å wavelength bins for optimally exposed LWP and SWP images. Repeatability measurements have also been made for both underexposed (*e.g.*, 20%, 40%, and 60% exposure levels) and coadded images (*e.g.*, 2, 3, and 4 images). In addition, repeatability errors measured in larger bin sizes (*i.e.*, 100Å and 200Å) and averaged over the useful range of *IUE* data are compared with other repeatability studies.

Analysis

The method of analysis used in this study is similar to the one used in other studies (*e.g.*, Bohlin 1978, Holm 1982, and Oliverson 1983). The data consist of groups of large-aperture point source observations. The images within each group were taken on the same day and using the same exposure times. This eliminates any errors that may be introduced by the time-dependent sensitivity degradation correction that is applied to the absolutely calibrated flux data. Although the correction is small, the fluxes have been corrected for camera head amplifier temperature (THDA) induced sensitivity variations (Garhart 1991). The LWP and SWP data are listed in Tables 1 and 2, respectively, and grouped by object and exposure level.

The fluxes within each group were ratioed to one another using all possible combinations of images. So, for example, a group that had five images would yield 10 ratios (*i.e.*, number of ratios = $n!/2(n-2)!$ where n equals the number of images in a particular group). In the ideal case, one would expect the ratios to be unity.

However, since the detectors are not perfect, the deviations of the ratios from unity represent the repeatability error for that particular ratio. The flux ratios were then binned at 25Å intervals in order to minimize the effects of random noise. Examples of this process are shown in Figure 1. The binned flux ratios were averaged in the following manner:

$$\text{Average Repeatability Error}_\lambda = (\Sigma |1 - \text{Ratio}_\lambda| / n) \times 100$$

where n is the total number of ratios that are summed. This equation represents the average repeatability error for a particular wavelength bin and is expressed as a percent. Another figure that is often cited in repeatability studies is the RMS deviation from unity, which is defined as:

$$\text{RMS Repeatability Error}_\lambda = \sqrt{\Sigma(\text{Ratio}_\lambda - 1)^2 / (n - 1)} \times 100$$

Initially, each group of images was analyzed separately. The results from each group were compared and found to be in agreement, so the binned ratios from each group were averaged to produce a final set of repeatability values as a function of wavelength bin. For the repeatability analysis of coadded images, the fluxes from 2, 3, or 4 images were averaged together before computing the ratios.

LWP Repeatability Results

LWP repeatability errors are listed in Tables 3-8. Unlike the SWP camera, a definite dependence of repeatability error with wavelength is seen. The repeatability seems to reach a minimum at around 2700Å and gradually increases in either wavelength direction. The overall repeatability for 100% and 60% exposures is around the same (3.3%). However, this comparison is deceptive as the errors for 60% exposures are quite large shortward of 2000Å. The overall error for 40% and 20% exposures increases dramatically to 5.3% and 16.6%, respectively. As one would expect, coadding images greatly improves the repeatability errors. Coadding 2 or 3 images results in an overall repeatability of around 2%. Although insufficient images were available to perform a test, presumably the errors decrease as one coadds more images.

SWP Repeatability Results

The results of the SWP analysis are listed in Tables 9-13. The SWP repeatability errors from object to object did not vary as much as the LWP. In the case of 100% exposures, the repeatability is fairly consistent from bin to bin. This is reflected in the low standard deviation of the final mean. The large errors seen at the extreme wavelength regions (1175Å and 1975Å) are not surprising as at this point the signal has dropped off considerably. The overall repeatability increase only slightly for 60% and 40% exposures in comparison to the LWP, although the errors for wavelengths

shortward of the 1250Å bin have increased. As is the case with the LWP analysis, the coadded SWP spectra show a decrease in the repeatability errors. The overall error is slightly less than 1% when coadding 4 spectra and around 1.6% when coadding 2 spectra.

Comparisons with Other Studies

The optimally exposed data were binned in wavelength intervals similar to the ones used in several other studies. These comparisons (shown in the table below) represent the differences between NEWSIPS and IUESIPS. The SWP NEWSIPS data shows an improvement over the IUESIPS counterpart, however, in the majority of the studies the LWP NEWSIPS data had somewhat poorer RMS repeatability errors when compared with IUESIPS. This higher error may be a reflection on the fact that my analysis was performed using an average of several stars. If the analysis is restricted to the same object as used by Cassatella (*i.e.*, BD+75° 325) the RMS deviations are smaller (*e.g.*, 3.0% versus 2.6% for Cassatella in the 2150–3100Å wavelength region).

$\lambda(\text{Å})$	Bin Size(Å)	RMS Error (%)	Repeatability Study	Garhart (1994)
1300–1900	100	2.5	Oliversen (1984)	1.6
1350–1950	50	2*	Loomis and Carini (1993)	1.7*
2100–3000	100	2.2	Oliversen (1984)	2.4
2000–3000	200	2.5	Harris and Cassatella (1983)	2.1
1950–2100	25	4.5	Cassatella, <i>et al.</i> (1992)	6.6
2150–3100	25	2.6	Cassatella, <i>et al.</i> (1992)	4.5
3200–3300	25	12.4	Cassatella, <i>et al.</i> (1992)	16.1

* Expressed as an average error rather than an RMS error.

Conclusions

Camera repeatability for observations taken very close in time depends upon the wavelength region and the signal level. The repeatability errors for observations taken far apart in time are expected to increase due to the uncertainties introduced by the application of the time-dependent sensitivity degradation correction. Overall SWP repeatability is approximately 2–3% even for low signal (40% level) exposures. The LWP, on the other hand, shows a dramatic increase in repeatability errors below the 60% exposure level. Thus, individuals who take repeated LWP observations of an object in a single shift at a reduced exposure level (*i.e.*, quantity over quality) will lose out when it comes time to look for variability.

References

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Table 1a: LWP Repeatability Images

Object Name	Image Number	Date (Yr/Day)	Exposure Time (secs.)	Exposure Level
G191 B2B	26799	1993/328	175.0	100%
	26800			
	26801			
	26802			
	26803			
	26804			
BD+28°4211	18498	1990/214	50.0	100%
	18499			
	18500			
	18501			
	18502			
	20483	1991/151	50.0	100%
	20484			
	20485			
	20486			
HD 60753	19115	1990/306	6.0	100%
	19116			
	19117			
	19118			
	19119			

Table 1b: LWP Repeatability Images

Object Name	Image Number	Date (Yr/Day)	Exposure Time (secs.)	Exposure Level
BD+75°325	14667	1988/354	20.0	100%
	14668			
	14669			
	14670			
	14671			
	14587	1988/337	4.1	20%
	14588			
	14589			
	14590			
	14591			
	14592	1988/347	4.1	20%
	14632			
	14633			
	14634			
	14635			
14636	1988/358	8.0	40%	
14698				
14699				
14700				
14701				
14702	HD 172883	1993/207	6.6	60%
26004				
26005				
26006				
26007				
26008				
26009				
26010				
26011				
26012				

Table 2a: SWP Repeatability Images

Object Name	Image Number	Date (Yr/Day)	Exposure Time (secs.)	Exposure Level
G191 B2B	49305	1993/328	90.0	100%
	49306			
	49307			
	49308			
	49309			
	49310			
BD+28°4211	39238	1990/198	26.0	100%
	39239			
	39240			
	39241			
	39242			
	39243			
	39372	1990/213	26.0	100%
	39373			
	39374			
	39375			
	39379	1990/214		
	39380			
	39381			
	39382			
	39383			
39384				
41751	41751	1991/153	27.0	100%
	41752			
	41753			
	41754			
	41755			
	41756			
	41757			

Table 2b: SWP Repeatability Images

Object Name	Image Number	Date (Yr/Day)	Exposure Time (secs.)	Exposure Level
BD+75°325	35115	1988/359	14.0	100%
	35116			
	35117			
	35118			
	35119			
	35120			
	35555	1989/045	5.6	40%
	35556			
	35557			
	35558			
	35559			
	35560			
	35564	1989/047	5.6	40%
	35565			
	35566			
	35567			
	35568			
HD 60753	47891	1993/169	4.6	40%
	47892			
	47893			
	47894			
	47895			
	47896			
	47897			
	47898	1993/169	7.0	60%
	47899			
	47900			
	47901			
	47902			
47903				
47904				

Table 3: LWP Repeatability Errors in 25Å Bins for 100% Exposures

$\lambda(\text{\AA})$	Repeatability Error (%)	RMS Error (%)	$\lambda(\text{\AA})$	Repeatability Error (%)	RMS Error (%)
1900	5.35	7.09	2625	1.87	2.21
1925	7.67	9.76	2650	2.39	2.79
1950	8.06	9.58	2675	2.27	2.69
1975	3.70	4.34	2700	1.86	2.14
2000	5.18	6.32	2725	2.52	2.84
2025	4.70	5.37	2750	2.74	3.22
2050	4.86	5.71	2775	2.70	3.06
2075	4.20	4.95	2800	2.22	2.61
2100	5.19	6.22	2825	2.27	2.69
2125	5.16	6.64	2850	1.59	2.03
2150	4.58	5.21	2875	2.80	3.51
2175	4.69	5.41	2900	3.04	3.49
2200	4.62	5.39	2925	2.86	3.50
2225	3.50	4.32	2950	3.02	3.62
2250	3.62	4.43	2975	2.62	3.09
2275	4.83	6.42	3000	3.54	4.15
2300	3.45	4.09	3025	4.00	4.79
2325	4.71	5.50	3050	9.95	11.90
2350	3.79	4.31	3075	4.97	5.92
2375	4.17	4.85	3100	4.81	5.64
2400	2.17	2.54	3125	4.61	5.63
2425	3.13	3.64	3150	5.03	6.25
2450	2.31	2.72	3175	7.39	8.86
2475	3.15	3.67	3200	10.74	12.93
2500	2.82	3.21	3225	9.21	10.91
2525	3.13	3.61	3250	11.97	14.94
2550	2.84	3.35	3275	13.41	15.80
2575	2.56	3.15	3300	16.26	20.54
2600	2.93	3.40	2000-3000	3.33 ± 1.04	4.35

Table 4: LWP Repeatability Errors in 25Å Bins for 60% Exposures

$\lambda(\text{\AA})$	Repeatability Error (%)	RMS Error (%)	$\lambda(\text{\AA})$	Repeatability Error (%)	RMS Error (%)
1900	29.73	45.26	2625	1.66	2.01
1925	326.74	1163.03	2650	1.99	2.35
1950	5.33	6.46	2675	2.69	3.52
1975	129.63	310.12	2700	2.68	3.31
2000	5.79	7.05	2725	2.59	3.07
2025	4.73	5.68	2750	1.97	2.36
2050	5.03	5.96	2775	2.35	3.15
2075	3.81	4.78	2800	2.86	3.63
2100	4.64	5.63	2825	2.40	3.08
2125	5.75	7.05	2850	2.71	3.26
2150	5.40	6.33	2875	2.82	3.45
2175	4.96	5.97	2900	2.66	3.33
2200	2.87	3.66	2925	1.40	1.82
2225	4.02	4.83	2950	2.93	3.62
2250	4.30	5.25	2975	1.73	2.32
2275	4.24	5.15	3000	2.19	2.75
2300	2.78	3.43	3025	1.65	2.02
2325	4.76	5.90	3050	6.07	7.55
2350	2.31	2.81	3075	2.84	3.37
2375	5.42	6.60	3100	3.64	4.50
2400	2.75	3.25	3125	4.61	5.75
2425	2.90	3.51	3150	5.98	7.26
2450	2.50	3.27	3175	3.83	4.82
2475	3.90	4.69	3200	6.11	7.47
2500	3.09	4.32	3225	8.95	10.97
2525	3.37	4.18	3250	9.77	12.10
2550	2.63	3.27	3275	8.64	10.55
2575	3.08	3.75	3300	9.86	12.54
2600	2.96	3.66	2000-3000	3.31 ± 1.19	4.24

Table 5: LWP Repeatability Errors in 25Å Bins for 40% Exposures

$\lambda(\text{Å})$	Repeatability Error (%)	RMS Error (%)	$\lambda(\text{Å})$	Repeatability Error (%)	RMS Error (%)
1900	26.58	38.57	2625	4.26	5.12
1925	216.97	301.94	2650	3.49	4.13
1950	96.03	156.59	2675	6.21	7.61
1975	38.75	53.66	2700	6.25	8.31
2000	6.52	7.94	2725	2.32	2.87
2025	6.83	8.77	2750	3.57	4.64
2050	6.95	8.75	2775	2.52	3.16
2075	13.06	16.82	2800	5.25	6.42
2100	6.89	8.47	2825	3.08	4.21
2125	3.62	4.57	2850	3.05	3.75
2150	7.52	9.05	2875	3.66	4.46
2175	16.21	19.70	2900	2.48	3.09
2200	4.74	6.07	2925	4.62	6.47
2225	6.70	8.00	2950	3.08	3.92
2250	13.41	17.06	2975	3.54	4.18
2275	5.77	7.09	3000	5.28	6.30
2300	5.75	8.18	3025	9.32	11.19
2325	3.60	4.22	3050	31.44	43.45
2350	5.66	6.56	3075	4.49	5.42
2375	4.12	5.08	3100	10.14	12.82
2400	4.01	5.20	3125	6.38	8.18
2425	3.56	4.41	3150	8.02	10.02
2450	8.15	10.02	3175	21.29	27.66
2475	4.84	6.17	3200	15.93	20.08
2500	3.24	3.95	3225	21.15	27.42
2525	1.99	2.57	3250	16.04	19.45
2550	4.96	5.88	3275	59.65	98.48
2575	2.74	3.42	3300	263.08	421.88
2600	3.51	4.30	2000-3000	5.29 ± 3.01	7.20

Table 6: LWP Repeatability Errors in 25Å Bins for 20% Exposures

$\lambda(\text{\AA})$	Repeatability Error (%)	RMS Error (%)	$\lambda(\text{\AA})$	Repeatability Error (%)	RMS Error (%)
1900	316.35	754.61	2625	3.90	4.61
1925	203.10	540.21	2650	5.44	6.54
1950	84.65	174.11	2675	3.30	4.50
1975	115.69	194.95	2700	4.89	6.31
2000	20.43	27.48	2725	4.42	5.47
2025	99.77	172.64	2750	4.22	5.17
2050	65.43	197.05	2775	3.45	4.88
2075	15.99	19.03	2800	4.30	5.22
2100	15.71	21.77	2825	7.45	8.77
2125	43.94	59.19	2850	6.51	7.96
2150	28.22	43.28	2875	2.55	3.27
2175	21.78	40.04	2900	5.58	7.34
2200	42.43	57.49	2925	6.09	7.52
2225	131.96	265.67	2950	5.64	7.26
2250	13.91	31.14	2975	7.21	9.19
2275	11.07	13.68	3000	6.98	8.56
2300	4.68	6.34	3025	8.55	10.60
2325	8.22	11.10	3050	111.41	331.97
2350	17.71	22.46	3075	10.98	13.90
2375	8.49	10.54	3100	6.83	8.30
2400	5.42	6.82	3125	12.68	15.65
2425	6.36	7.70	3150	12.75	15.09
2450	6.11	7.76	3175	24.37	34.05
2475	5.98	7.42	3200	38.58	61.46
2500	5.38	6.42	3225	42.07	50.95
2525	6.36	8.47	3250	426.34	1381.20
2550	5.01	6.04	3275	249.19	475.49
2575	4.54	5.74	3300	126.18	203.15
2600	5.01	6.23	2000-3000	16.63± 26.34	60.35

Table 7: LWP Repeatability Errors in 25Å Bins for Coadded (2) Images

$\lambda(\text{Å})$	Repeatability Error (%)	RMS Error (%)	$\lambda(\text{Å})$	Repeatability Error (%)	RMS Error (%)
1900	5.24	7.14	2625	1.62	1.97
1925	7.23	9.08	2650	1.60	2.04
1950	5.92	7.31	2675	1.42	1.91
1975	2.55	3.04	2700	1.33	1.69
2000	2.36	3.55	2725	1.70	2.13
2025	2.11	2.87	2750	1.87	2.39
2050	2.99	3.97	2775	2.09	2.48
2075	3.62	4.65	2800	1.97	2.39
2100	4.42	5.35	2825	1.23	1.71
2125	2.96	3.72	2850	0.87	1.16
2150	2.99	3.85	2875	1.87	2.44
2175	3.64	4.27	2900	1.90	2.36
2200	3.27	4.21	2925	2.64	3.58
2225	2.88	3.65	2950	1.67	2.05
2250	3.24	3.96	2975	1.52	2.22
2275	2.30	3.04	3000	2.01	2.66
2300	2.45	3.25	3025	1.82	2.54
2325	2.98	3.84	3050	5.67	8.33
2350	2.67	3.23	3075	1.91	2.59
2375	2.95	3.62	3100	3.15	3.99
2400	1.37	1.63	3125	3.52	4.36
2425	1.39	1.67	3150	4.01	4.91
2450	1.69	2.06	3175	5.43	7.06
2475	2.04	2.56	3200	9.55	11.34
2500	2.20	2.56	3225	5.79	7.13
2525	2.11	3.48	3250	11.27	14.90
2550	2.39	2.87	3275	7.92	9.78
2575	1.27	1.76	3300	6.87	8.26
2600	2.07	2.88	2000-3000	2.24 ± 0.77	2.91

Table 8: LWP Repeatability Errors in 25Å Bins for Coadded (3) Images

$\lambda(\text{Å})$	Repeatability Error (%)	RMS Error (%)	$\lambda(\text{Å})$	Repeatability Error (%)	RMS Error (%)
1900	3.28	4.47	2625	1.19	1.77
1925	6.02	7.14	2650	2.17	2.64
1950	4.66	5.62	2675	1.30	1.55
1975	1.76	2.53	2700	1.29	1.83
2000	2.61	3.09	2725	1.79	2.55
2025	2.95	4.14	2750	0.55	0.64
2050	3.71	5.19	2775	1.52	1.99
2075	2.97	3.80	2800	0.70	0.90
2100	4.14	4.87	2825	0.71	1.06
2125	2.31	3.15	2850	0.36	0.48
2150	1.23	1.49	2875	0.44	0.66
2175	2.13	3.40	2900	0.84	1.20
2200	2.19	3.42	2925	1.38	1.95
2225	2.50	3.66	2950	1.28	1.55
2250	2.14	3.03	2975	0.92	1.28
2275	3.25	4.42	3000	1.31	1.73
2300	3.35	4.58	3025	1.38	2.37
2325	3.19	4.24	3050	8.05	10.94
2350	2.54	3.13	3075	1.93	2.58
2375	3.06	3.59	3100	1.41	1.86
2400	1.34	1.56	3125	3.69	5.23
2425	1.48	2.12	3150	3.05	3.60
2450	1.82	2.19	3175	6.00	7.55
2475	1.69	2.01	3200	5.23	6.76
2500	1.48	1.85	3225	4.51	5.88
2525	2.26	3.29	3250	7.61	11.74
2550	2.97	3.66	3275	5.44	10.16
2575	1.65	2.58	3300	5.04	6.13
2600	0.89	1.19	2000-3000	1.89 ± 0.95	2.44

Table 9: SWP Repeatability Errors in 25Å Bins for 100% Exposures

$\lambda(\text{\AA})$	Repeatability Error (%)	RMS Error (%)
1175	4.52	6.15
1200	2.37	3.25
1225	2.30	3.52
1250	1.74	2.08
1275	2.36	3.09
1300	2.21	2.82
1325	2.43	3.10
1350	2.52	3.15
1375	1.94	2.39
1400	2.41	3.01
1425	1.70	2.19
1450	2.43	2.88
1475	1.89	2.37
1500	2.13	2.65
1525	2.20	2.85
1550	1.90	2.40
1575	2.01	2.46
1600	2.37	3.05
1625	2.26	2.78
1650	2.24	3.00
1675	2.28	2.76
1700	2.12	2.60
1725	1.68	2.14
1750	1.77	2.25
1775	2.34	2.95
1800	2.59	3.20
1825	2.25	2.76
1850	2.10	2.53
1875	2.19	2.65
1900	2.72	3.42
1925	2.01	2.61
1950	2.57	3.15
1975	32.60	32.91
1250-1950	2.18 ± 0.28	2.74

Table 10: SWP Repeatability Errors in 25Å Bins for 60% Exposures

$\lambda(\text{Å})$	Repeatability Error (%)	RMS Error (%)
1175	16.74	23.80
1200	11.75	15.36
1225	24.79	31.75
1250	3.80	4.57
1275	2.64	3.36
1300	1.95	2.67
1325	2.41	3.26
1350	3.06	3.67
1375	1.42	1.72
1400	3.06	3.73
1425	2.19	2.88
1450	3.51	4.33
1475	4.38	5.60
1500	2.99	3.73
1525	6.59	11.27
1550	5.16	6.19
1575	4.04	5.10
1600	2.90	3.47
1625	3.14	3.75
1650	2.21	2.69
1675	1.46	1.79
1700	2.63	3.25
1725	1.41	1.83
1750	2.10	2.58
1775	1.96	2.38
1800	1.89	2.32
1825	2.42	2.87
1850	1.14	1.39
1875	2.41	2.94
1900	2.67	3.24
1925	2.72	3.38
1950	1.70	2.07
1975	31.05	31.89
1250-1950	2.76 ± 1.18	4.01

Table 11: SWP Repeatability Errors in 25Å Bins for 40% Exposures

$\lambda(\text{Å})$	Repeatability Error (%)	RMS Error (%)
1175	7.60	10.74
1200	11.55	21.22
1225	17.08	29.86
1250	2.16	2.66
1275	3.39	4.13
1300	2.48	3.11
1325	2.18	2.58
1350	2.25	2.80
1375	2.72	3.48
1400	4.53	5.69
1425	2.55	3.10
1450	2.51	3.10
1475	3.84	4.62
1500	4.02	5.28
1525	3.83	4.71
1550	4.66	5.55
1575	4.17	5.45
1600	3.28	4.22
1625	2.43	2.94
1650	4.01	5.32
1675	4.21	5.23
1700	3.80	4.76
1725	3.03	3.72
1750	3.24	3.85
1775	3.09	4.08
1800	3.01	3.79
1825	3.34	3.97
1850	3.86	4.64
1875	2.60	3.12
1900	3.13	4.22
1925	2.93	3.57
1950	2.45	3.09
1975	32.02	32.44
1250-1950	3.23 ± 0.74	4.09

Table 12: SWP Repeatability Errors in 25Å Bins for Coadded (2) Images

$\lambda(\text{Å})$	Repeatability Error (%)	RMS Error (%)
1175	2.43	3.46
1200	1.20	1.70
1225	1.88	2.33
1250	1.06	1.35
1275	1.74	2.30
1300	1.76	2.14
1325	2.05	2.74
1350	2.13	2.66
1375	1.95	2.31
1400	1.81	2.35
1425	1.33	1.60
1450	1.58	1.96
1475	1.26	1.65
1500	1.72	2.34
1525	1.68	2.20
1550	0.84	1.19
1575	1.31	1.58
1600	1.75	2.32
1625	1.54	1.86
1650	1.31	1.62
1675	1.71	2.09
1700	1.48	1.79
1725	1.33	1.69
1750	1.27	1.51
1775	1.72	2.20
1800	1.86	2.38
1825	1.86	2.22
1850	1.36	1.68
1875	1.65	2.03
1900	2.10	2.53
1925	1.89	2.35
1950	2.09	2.51
1975	32.84	33.80
1250-1950	1.63 ± 0.32	2.02

Table 13: SWP Repeatability Errors in 25Å Bins for Coadded (4) Images

$\lambda(\text{\AA})$	Repeatability Error (%)	RMS Error (%)
1175	1.24	1.51
1200	0.83	1.20
1225	0.89	1.33
1250	0.73	0.93
1275	1.34	1.73
1300	0.81	1.19
1325	1.38	1.84
1350	1.79	2.18
1375	1.30	1.54
1400	0.98	1.33
1425	0.93	1.15
1450	0.45	0.79
1475	0.67	1.03
1500	1.21	1.68
1525	1.09	1.37
1550	0.65	0.98
1575	0.78	0.93
1600	0.78	1.06
1625	1.03	1.51
1650	0.38	0.51
1675	1.21	1.59
1700	0.52	0.85
1725	0.96	1.18
1750	0.62	0.83
1775	1.03	1.38
1800	0.98	1.30
1825	0.86	1.27
1850	0.68	0.98
1875	1.03	1.27
1900	1.01	1.24
1925	1.07	1.25
1950	1.09	1.41
1975	32.72	36.60
1250-1950	0.94 ± 0.31	1.17

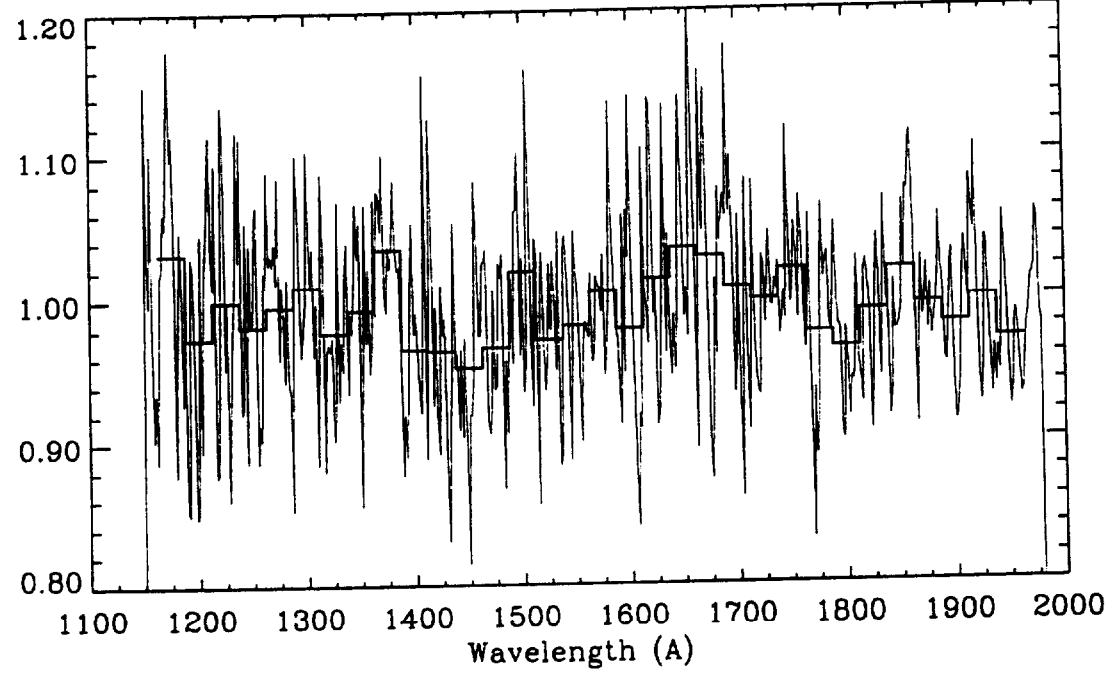
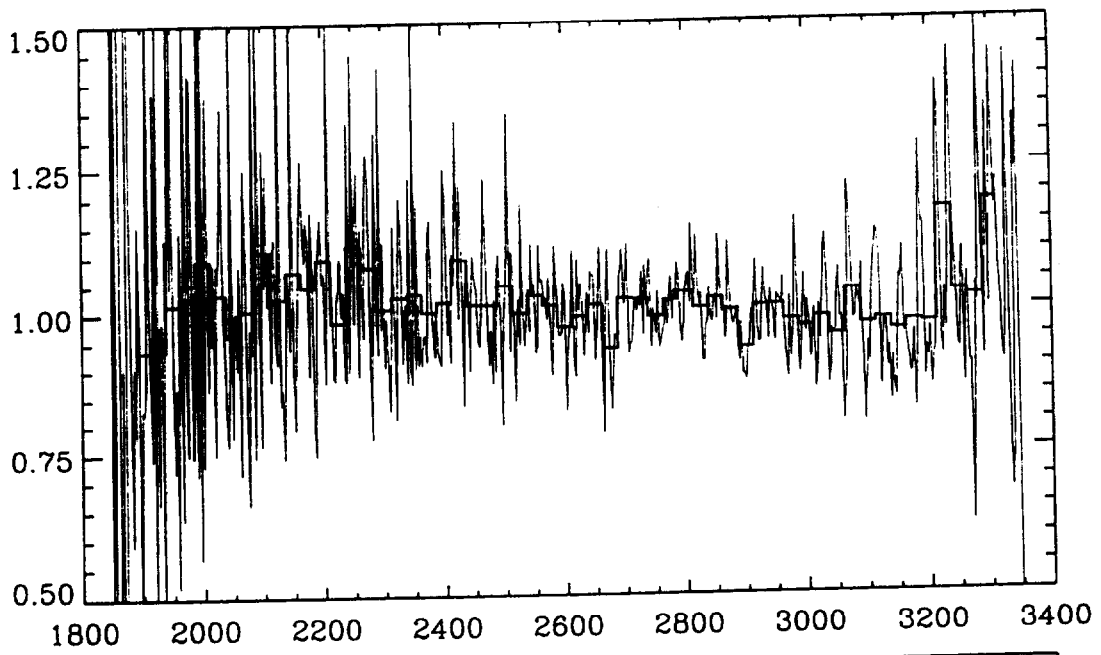


Figure 1: Sample LWP (top) and SWP (bottom) repeatability ratio.