SWP and LWR Linearity Error Report

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Introduction

The SWP and LWR cameras both suffer from non-linearities (Bohlin, et al., 1980). Examples of these linearity errors are shown in this report, for a variety of under and over-exposures. Their stability with time is discussed. Finally, sample linearity errors for spectra obtained with moderate to high backgrounds are also shown. For a discussion of the LWP linearity errors see the report by Hathaway (1982). *

Observation and Data Analysis Technique

HD 60753, a sixth magnitude B3 IV star, is the standard star used for linearity studies. Figure 1 is a plot of the Net Flux Numbers for typical SWP and LWR trailed spectra of HD 60753. In order to obtain the best signal-to-noise, the spectra for this study were all trailed. For each image of a given camera and percent exposure level, the trail rates were duplicated exactly. The spacecraft attitude is held by use of the gyros alone during the trailing procedure. If necessary, several minutes prior to the start of an exposure is spent in monitoring and taking out the thermal drifts by trimming the gyros. This is done to prevent drifting of the star and loss of signal during the exposure.

To compare a test image (typically a non-optimum exposure) with a standard 100% exposure level image, the test image was divided by a reference image. For each flux ratio the following steps were followed:

(1) The fluxes were generated for each image from the standard ESLO file provided by IUE SIPS. Due to an error in the SWP Intensity Transfer Function (ITF), images processed at GSFC prior to July 7, 1979 may contain non-linearities (Holm et al., 1982). For this report, any images affected by this problem have been reprocessed using the corrected software.

(2) For each flux ratio, the numerator spectra were interpolated to the wavelength of the denominator spectra by use of a spline interpolation routine.

(3) The test spectra were then divided by an 100% reference spectrum. Where appropriate two test spectra were averaged prior to the ratioing.

(4) Finally, each ratio was smoothed with a 5 point median filter in order to eliminate large spikes and also smoothed with an 11 point boxcar filter.

* Editor's Note: A Report on LWP Linearity errors will appear in a future issue of the IUE Newsletter.

(5) To minimize the effects of sensitivity variations (Sonneborn and Schiffer, 1982), generally the spectra used to derive a flux ratio for a given camera were obtained on the same day. The two exceptions to this are figures 5 and 13. However, the LWR and SWP ratios on an individual plot may represent data taken several months apart.

Reproducibility

Figures 2a-c show the ratio of fluxes from pairs of identical, optimally-exposed trailed spectra of HD 60753. Ideally, each ratio should be equal to unity. For each of these three figures, the flux ratios were also averaged over 100 angstrom bandpasses and are listed in Table 1. The binned flux ratios for the SWP show an rms deviation of 3.1% from unity. The LWR flux ratios show a slightly smaller rms deviation of 2.0% from unity.

For a consistency check, the same spectra as were used for figure 1 in the study by Holm (1982), were also used to construct figure 2b. The two figures give similar linearity errors, indicating that the technique used in the two studies was similar. The exact smoothing routines differed slightly between the two studies, but the average errors are similar.

A change in the camera head amplifier temperature (THDA) during the exposure sequence is a possible source of sensitivity errors. As the camera temperature increases the sensitivity decreases at a rate of .5%/degree for the SWP and 1.1%/degree for the LWR (Schiffer, 1982). Changes in the camera temperature therefore, should affect the reproducibility errors. The camera temperature was checked for the exposures used in figures 2a to c. The change in temperature along with the cooresponding relative sensitivity factors are listed in table 2. After correction for temperature induced sensitivity changes, the rms deviation for the SWP is essentially unchanged while the rms deviation for the LWR is reduced slightly to 1.5%.

Sonneborn and Schiffer (1982) report rms errors for individual point source spectra of 3.5% for the SWP spectra and 3.8% for the LWR spectra. The reproducibility for trailed SWP spectra appear to be consistent with the 2 to 3 percent reported by Holm (1982). The reproducibility of the LWR trailed spectra, on the other hand, appears to be better than the reproducibility for point source spectra.

It should be noted that the statistical sample size for this study is very small - only 6 images were used for the estimate of the trailed reproducibility errors. By contrast, Sonneborn and Schiffer's errors are based on a larger sample size. In addition their errors are for point spectra and it is uncertain whether the reproducibility of point source and trailed spectra are comparable.

Linearity Errors for Spectra at a Given Epoch

Figures 3 through 6 illustrate typical linearity errors for a variety of non-optimum exposure levels.

Figure 3 shows the linearity errors for the ratio of spectra of 120%/100% exposure levels. Both the SWP and LWR 120% spectra contain pixels extrapolated beyond the highest level of the ITF. For the SWP exposure, the extrapolated pixels are between about 1240 and 1350 angstroms and for the LWR are between 2550 and 2890 angstroms. The errors on this plot are within the reproducibility error limits (see Figure 2), even though the 120% spectra contain extrapolated pixels.

Figures 4 through 6 show the linearity errors for the ratios of 60%/100%, 40%/100%, and 30%/100% respectively. For the LWR, as the exposure level is reduced, the derived flux is too high relative to the flux obtained with an optimum exposure level (see also Holm (1982) and Hathaway (1983)). For the SWP, the effect is a function of wavelength. At the shortest wavelengths the derived flux is too low relative to an optimum exposure, while at the longest wavelengths the flux is too high.

Stability of Linearity Errors with Time

Figures 6 to 11 show the linearity errors for the 30%/100% flux ratios covering the time period from November 1978 through March 1983. No appropriate SWP spectra were obtained in February or December of 1981. Therefore, figures 7 and 8 contain LWR flux ratios only. The average slope and size of the deviations from unity are all roughly similar to the value obtained for November 1978 (Figure 6). Except for the apparent random noise fluctuations, there does not appear to have been a measurable change in the linearity since November 1978, despite known sensitivity changes (Sonneborn and Schiffer, 1982).

Linearity Errors for Spectra with High Background

Figures 12 and 13 illustrate typical linearity errors for spectra obtained with moderate and high backgrounds. The increased background signal for these images was produced by exposing the camera to a Tungsten Flood Lamp. The average peak 'moderate' background level for the SWP image was 45 DN or 2200 FN, and for the LWR image was 55 DN or 5300 FN. The average peak 'high' background level for the LWR was 95 DN or about 13200 FN.

Non-optimum spectra with high backgrounds suffer from large linearity errors. As can been seen from figure 13, the flux derived from an under-exposed spectra with a high background can be too low by as much as 20% relative to an optimum exposure (with a low background). The background produced by the tungsten flood lamp is assumed to be similar to the background induced by the field particle radiation. This large linearity error can, therefore, be very important for spectra obtained during the US2 shift when the field particle radiation from the Van Allen Belts.

is high.

Table 1
BINNED REPRODUCIBILITY ERRORS

Linearity Flux Ratios

Central Wavelength	Figure 2a		Figure 2b		Figure 2c	
	FR	Sigma	FR	Sigma	FR	Sigma
1300	.956	.009	.986	.028	.979	.021
1400	.954	.009	.995	.021	.977	.009
1500	.952	.014	.982	.017	.981	.017
1600	.962	.016	.991	.014	.984	.021
1700	.950	.015	.987	.014	.973	.011
1800	.951	.013	.971	.012	.982	.012
1900	.969	.012	.976	.017	.994	.013
SWP	mean dev = .0261 RMS dev = .0305		Not corrected for THDA sensitivity variation.			
2100	.960	.021	1.000	.020	1.010	.017
2200	.978	.016	.988	.013	.986	.016
2300	1.008	.018	.990	.015	.989	.013
2400	1.001	.022	.968	.016	.995	.011
2500	.995	.012	.971	.012	.981	.023
2600	.983	.009	.967	.012	.977	.011
2700	.976	.009	.990	.012	.977	.009
2800	.966	.009	.991	.010	.996	.013
2900	.971	.008	.994	.012	.999	.016
LWR	mean dev = .0157 RMS dev = .0196		Not corrected for THDA sensitivity variation.			

* Flux Ratios (FR) are binned into 100 angstrom bandpasses

Figure 2a: SWP 16582 / SWP 16587
LWR 12818 / LWR 12823

Figure 2b: SWP 14604 / LWR 14608
LWR 12117 / LWR 12123

Figure 2c: SWP 18057 / SWP 18062
LWR 14187 / LWR 14191

Table 2
Camera Temperature Changes and Sensitivity Ratios

	Delta Temperature (Numerator - Denominator)			Relative Sensitivity Factors(%)		
Figure	2a	2b	2c	2a	2b	2c
SWP	.62	-.67	-.34	-.31	+.34	+.17
LWR	-1.35	-.34	-1.30	+1.49	+.37	+1.43

* Relative Sensitivity Factors = the percent of sensitivity change between the first image and the last image taken in the sequence.

References

Bohlin, R.C., Holm, A.V., Savage, B.D., Snijders, M.A.J. and Sparks, W.M. 1980, Astron. Astrophys., 85, p. 1.
Holm, A.V. 1982, "The Photometric Performance of the IUE", in "Advances in UV Astronomy. Four Years of IUE Research", NASA CP-2238, p. 339.
Holm, A., Bohlin, R.C., Cassatella, A., Ponz, D. P. and Schiffer, F. H. 1982, Astron. Astrophys., 112, p. 341.
Hathaway, W., 1983, report presented at the March 1983 IUE Users Committee meeting.
Schiffer, F.H. 1982, NASA IUE Newsletter, No. 18, p. 64.
Sonneborn, G. and Schiffer, F.H., 3rd, 1982, "Quick Look Sensitivity Monitoring. VI", report presented at the September 1982 IUE Users Committee meeting.

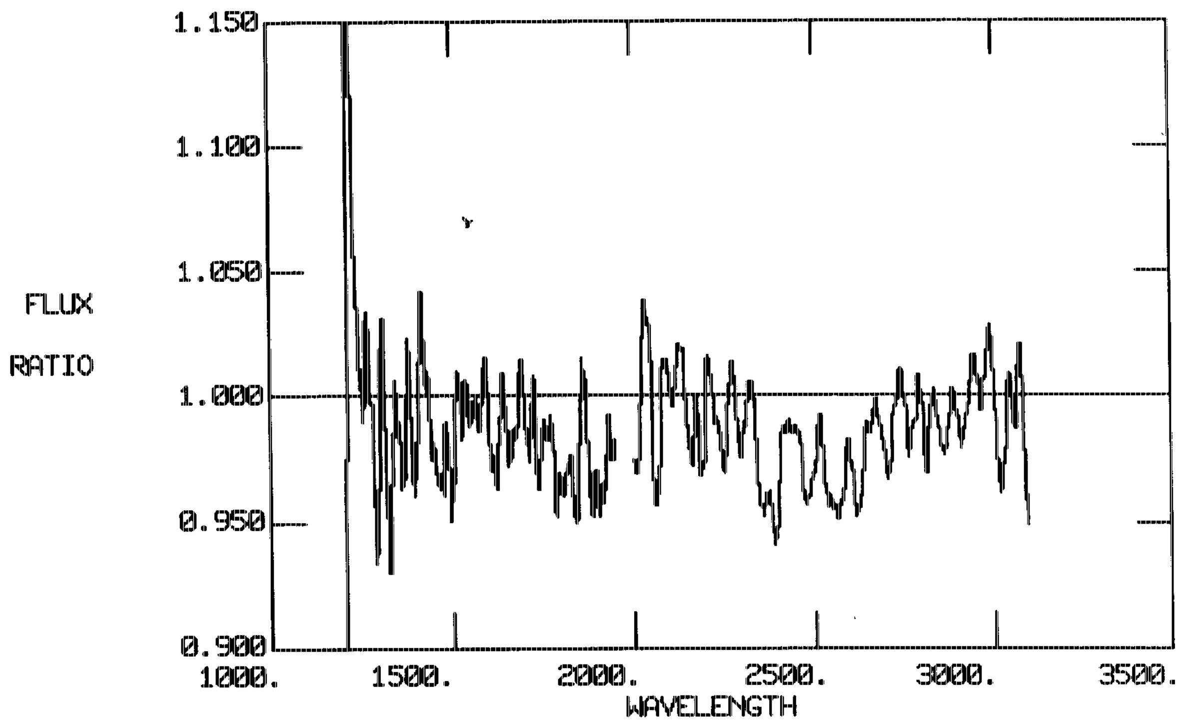

Figure 2b. Reproducibility - Fluxes from 100% / 100%
SWP 14604 / SWP 14608 (July, 1981)
LWR 12117 / LWR 12123 (Dec., 1981)

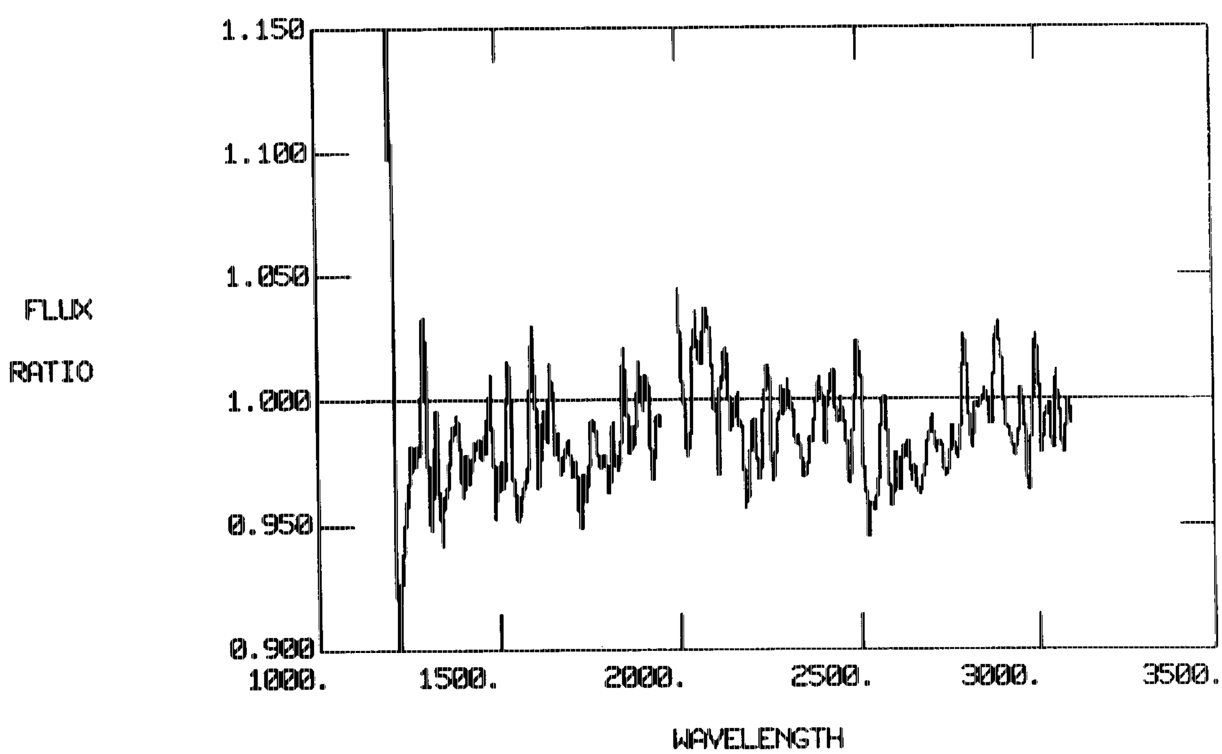

Figure 2c. Reproducibility in September 1982
SWP 18057 / SWP 18062
LWR 14187 / LWR 14191

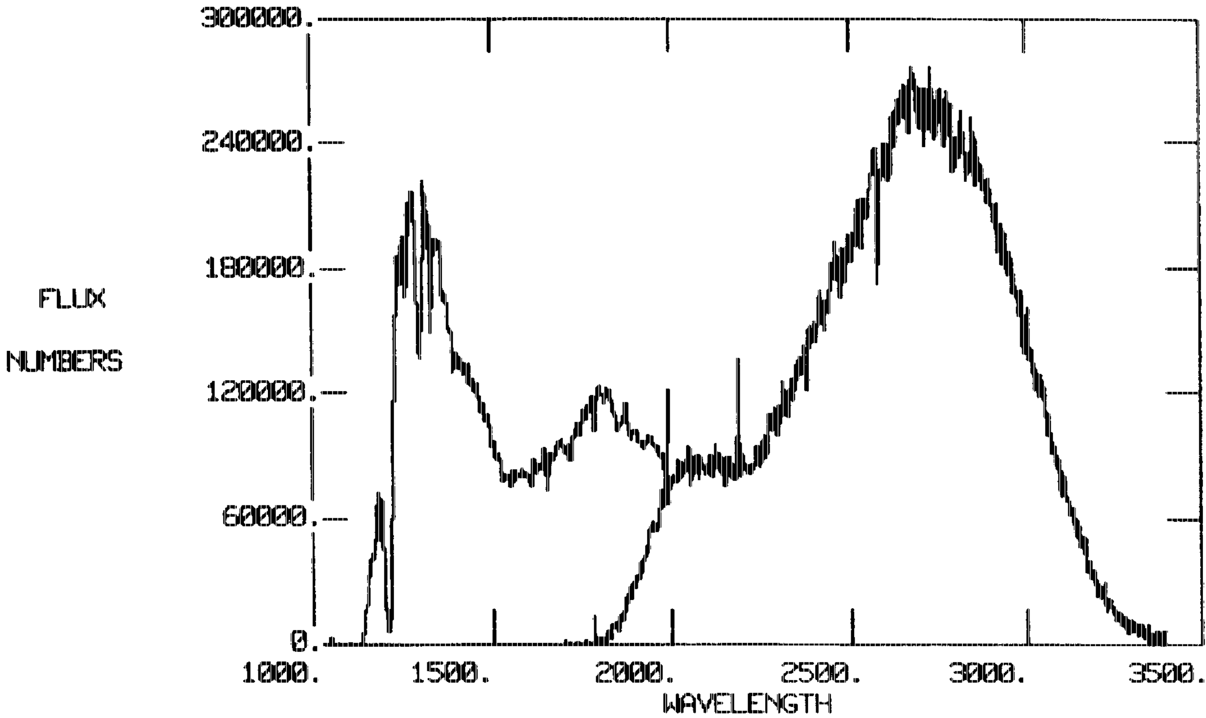

Figure 1. Net Flux Numbers for 100% Trailed Reference Spectra of HD 60753. SWP 3219 and LWR 2822; November, 1978

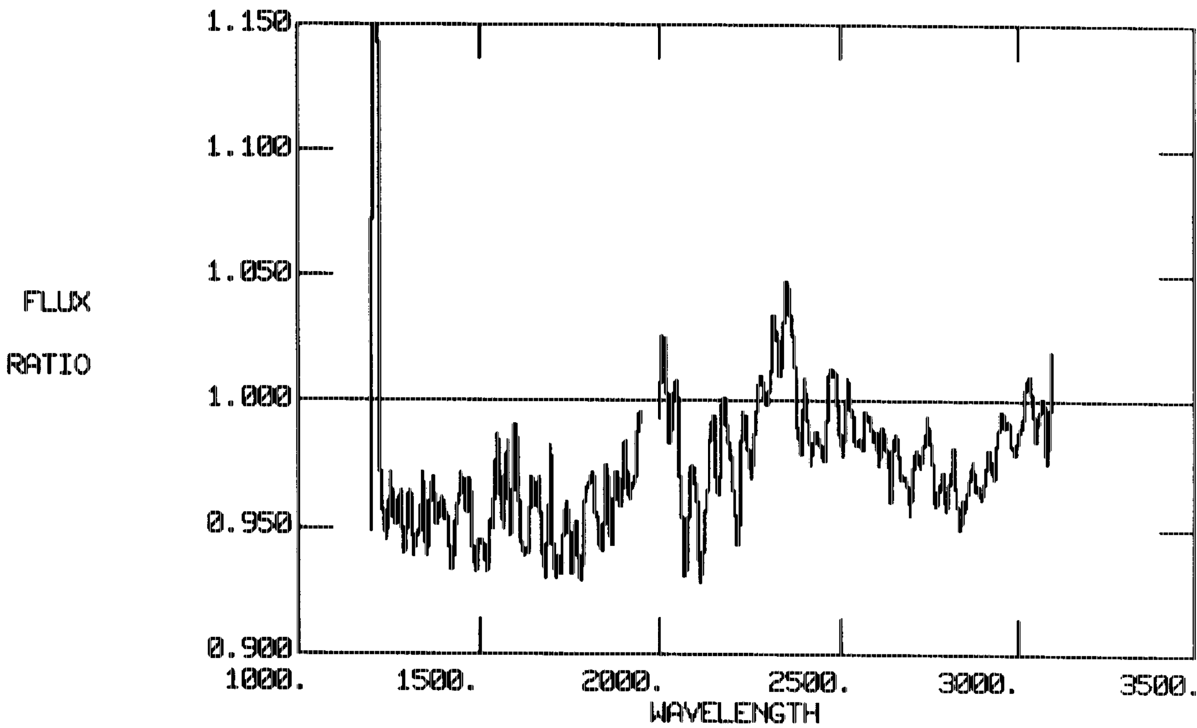

Figure 2a. Reproducibility - Fluxes from 100% / 100% SWP 16582 / SWP 16587 and LWR 12818 / LWR 12823 March, 1982

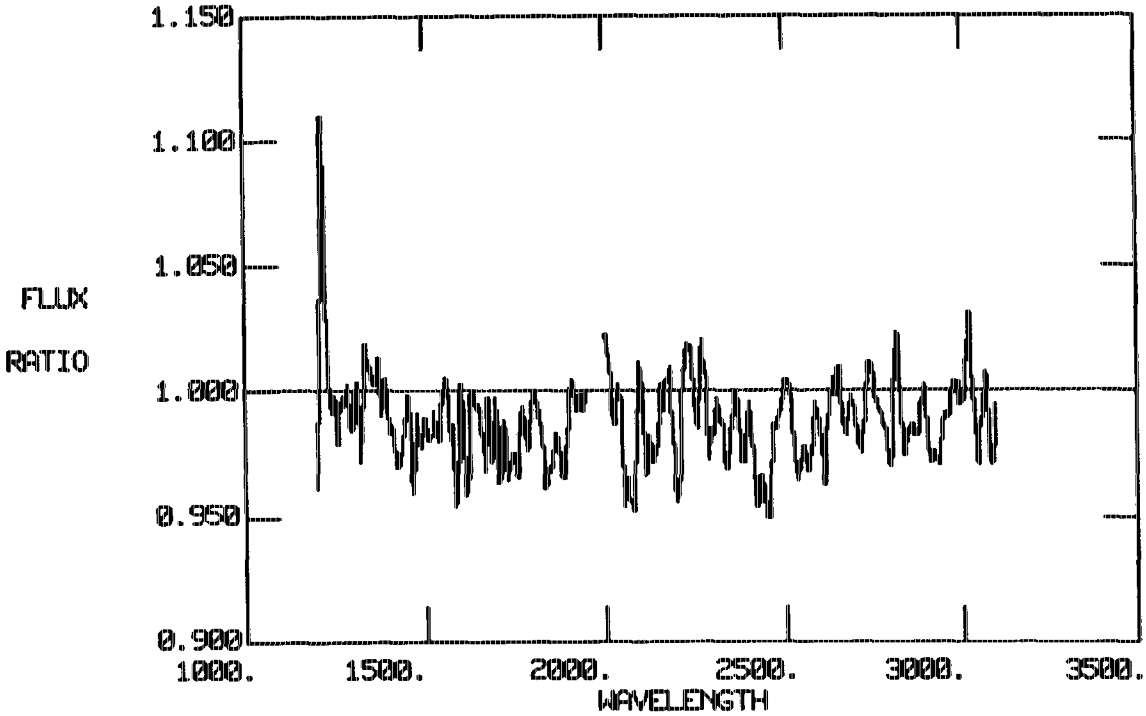

Figure 3. 120%/100% Linearity Errors
SWP 16585 / SWP 16587
LWR 12820 / LWR 12823
March, 1982

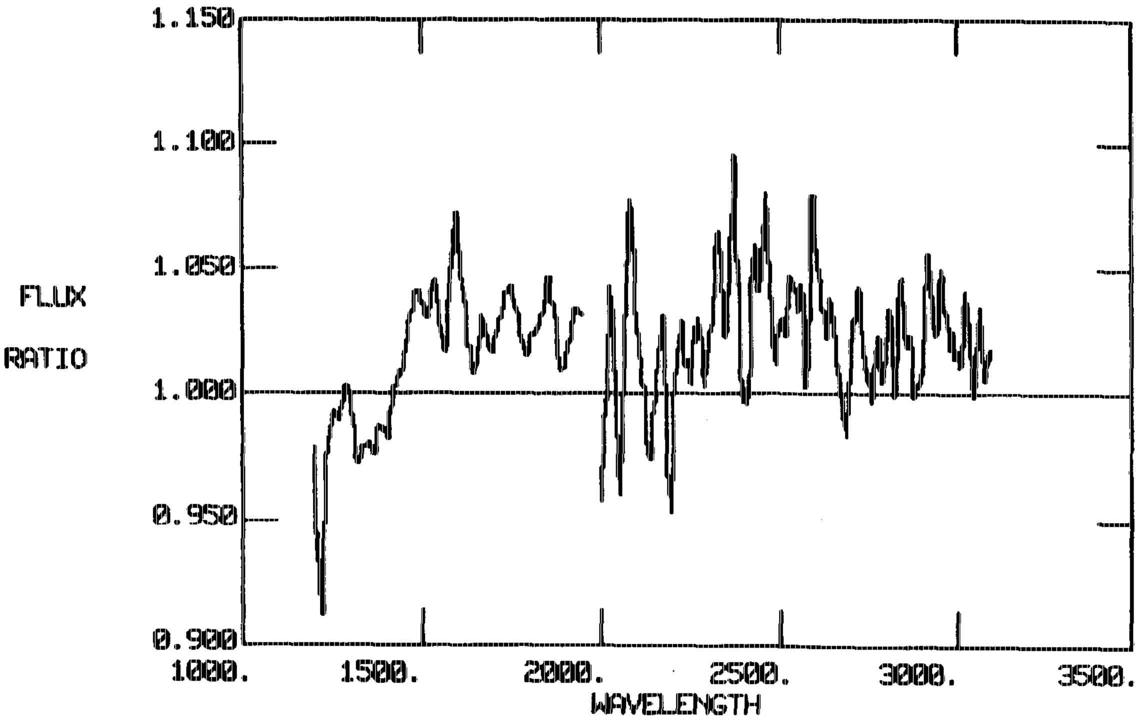

Figure 4. 60% / 100% Linearity Errors
SWP 3223 / SWP 3219
LWR 2826 / LWR 2822
November, 1978

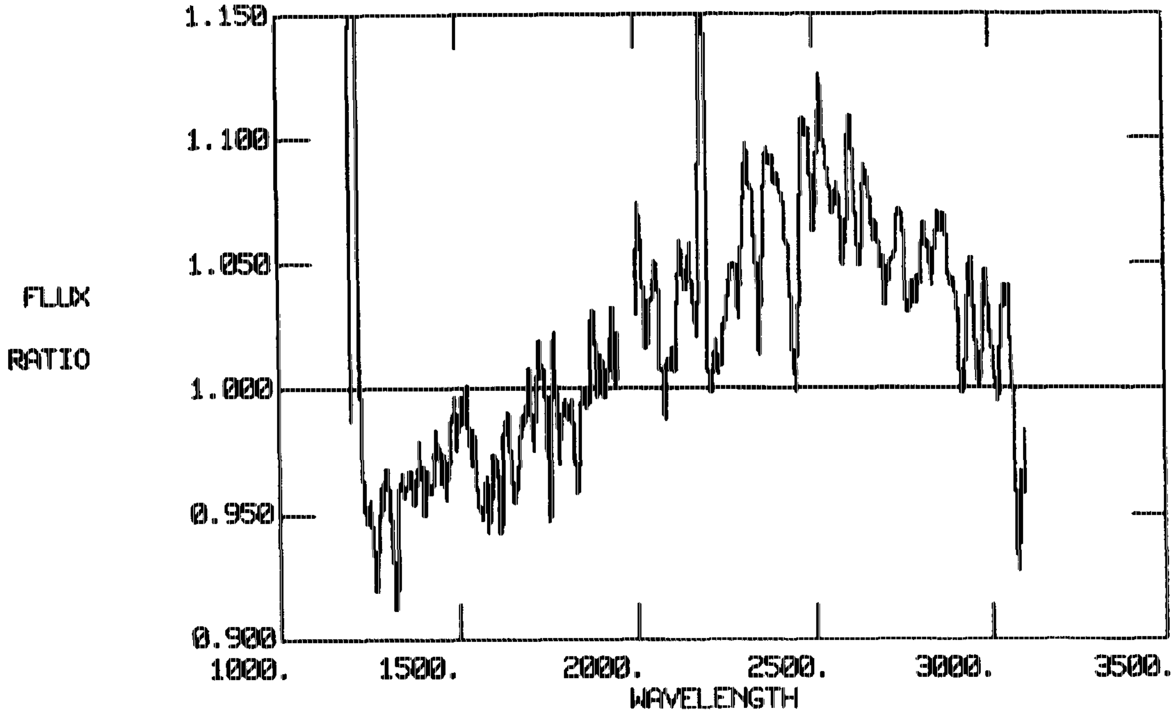

Figure 5. 40% / 100% Linearity Errors
SWP 16583 / SWP 16587 Mar, 1982
LWR 12120 / LWR 12823 Dec, 1981 / Mar, 1982

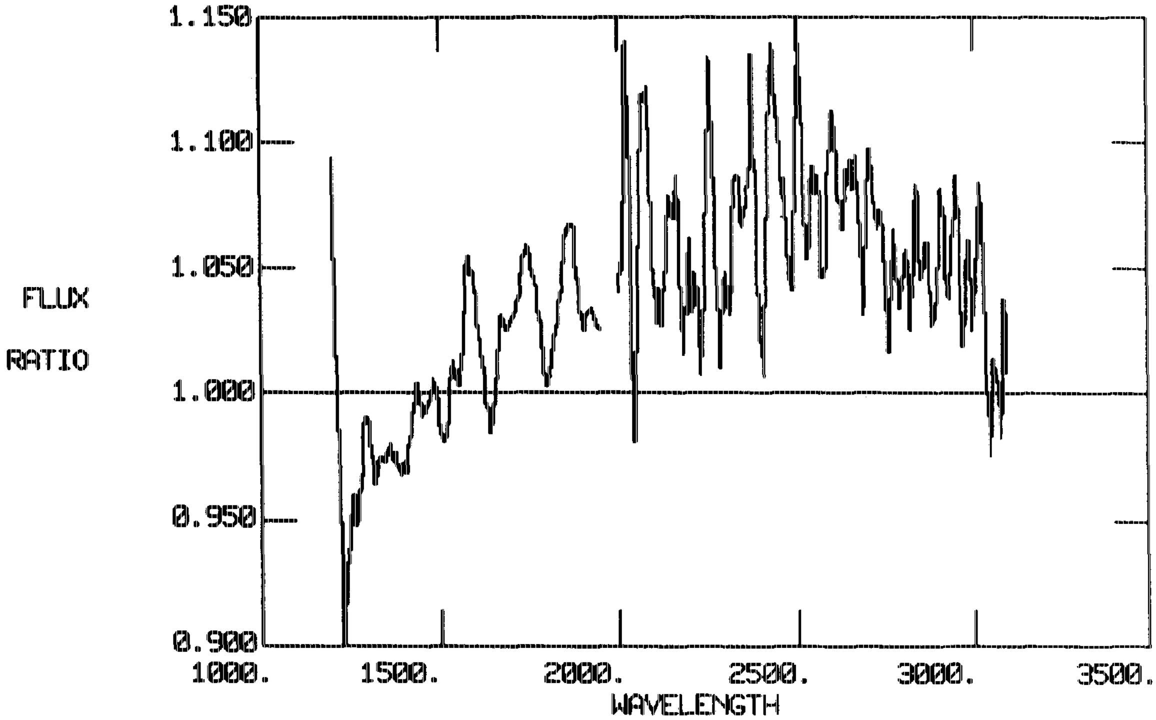

Figure 6. 30% / 100% Linearity Errors in November 1978
SWP 3222 / SWP 3219
LWR 2825 / LWR 2822

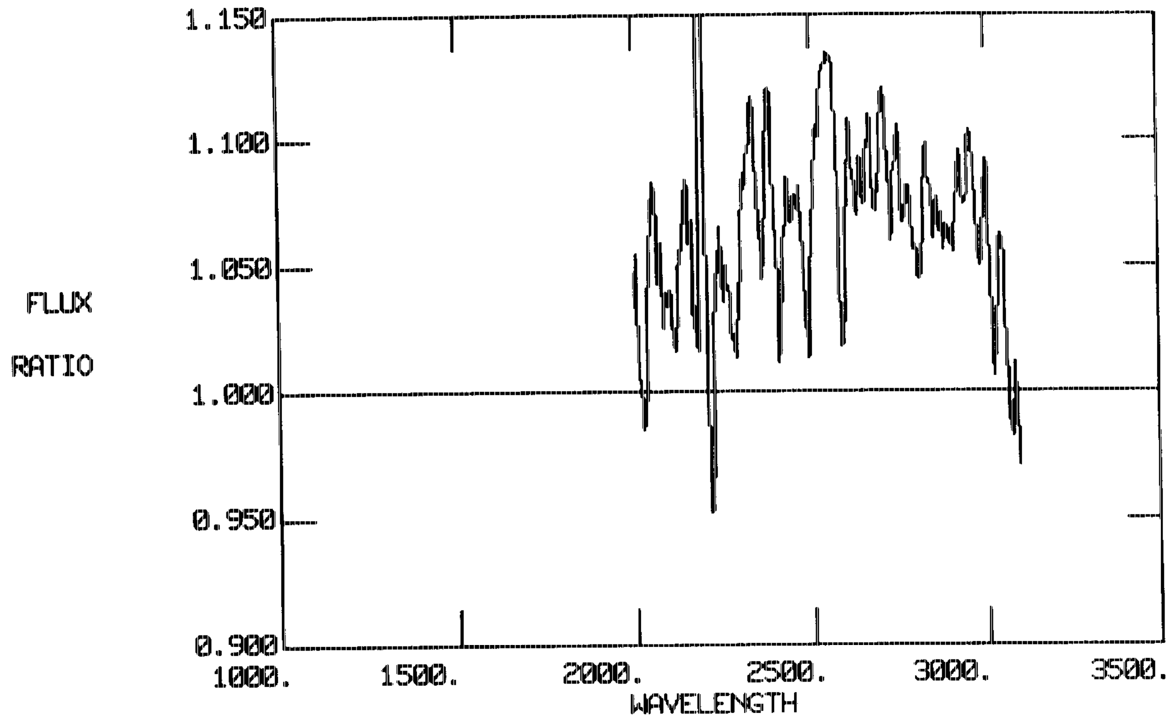

Figure 7. 30% / 100% Linearity Errors in February, 1981
((LWR 9981 + LWR 9985)/2) / LWR 9984

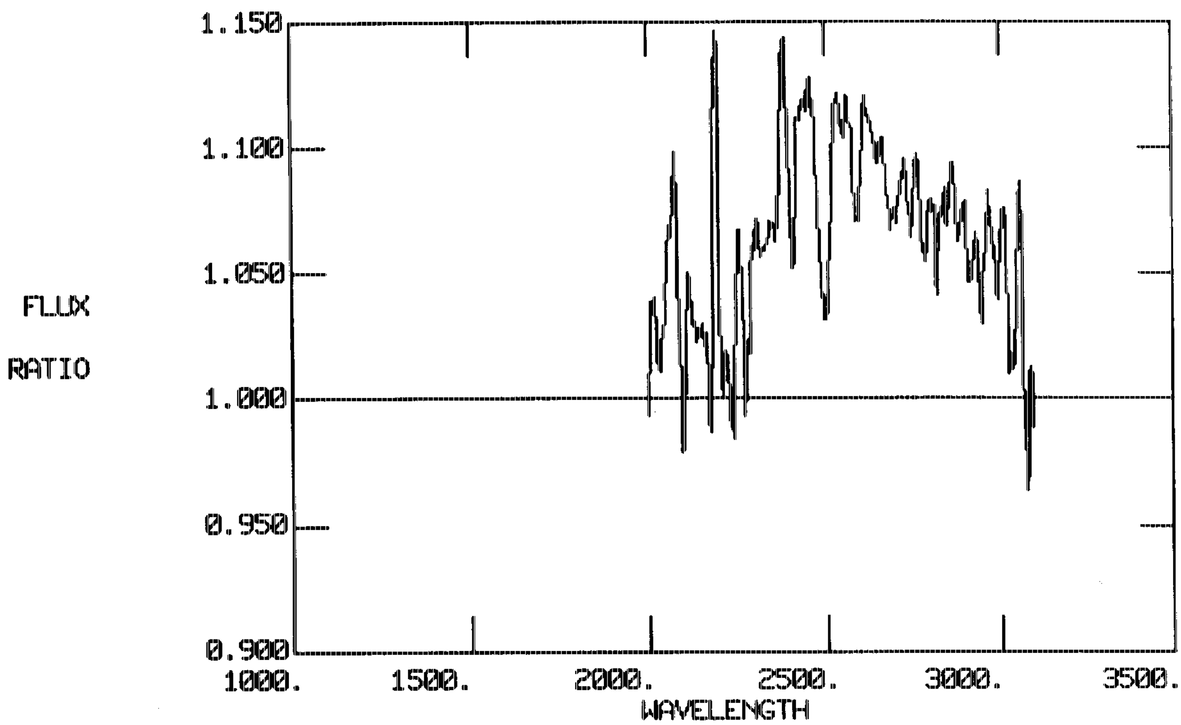

Figure 8. 30% / 100% Linearity Errors in December 1981
((LWR 12118 + LWR 12121)/2) / LWR 12117

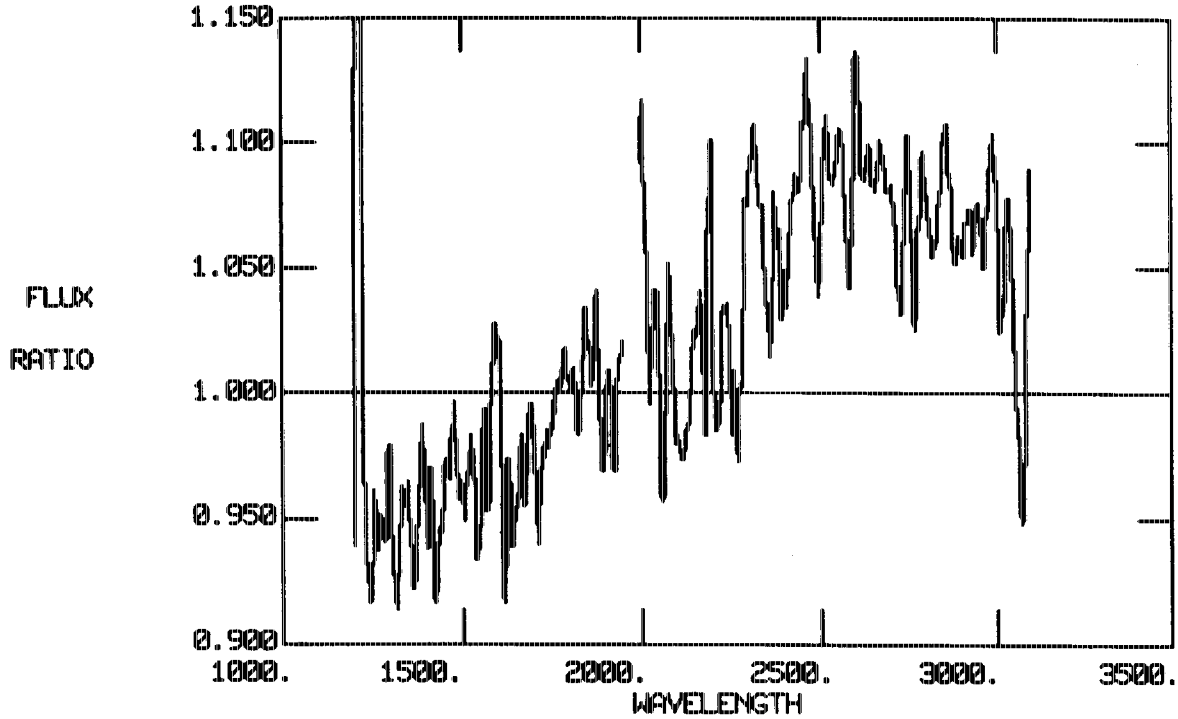

Figure 9. 30% / 100% Linearity Errors in March, 1982
SWP 16584 / SWP 16587
LWR 12819 / LWR 12823

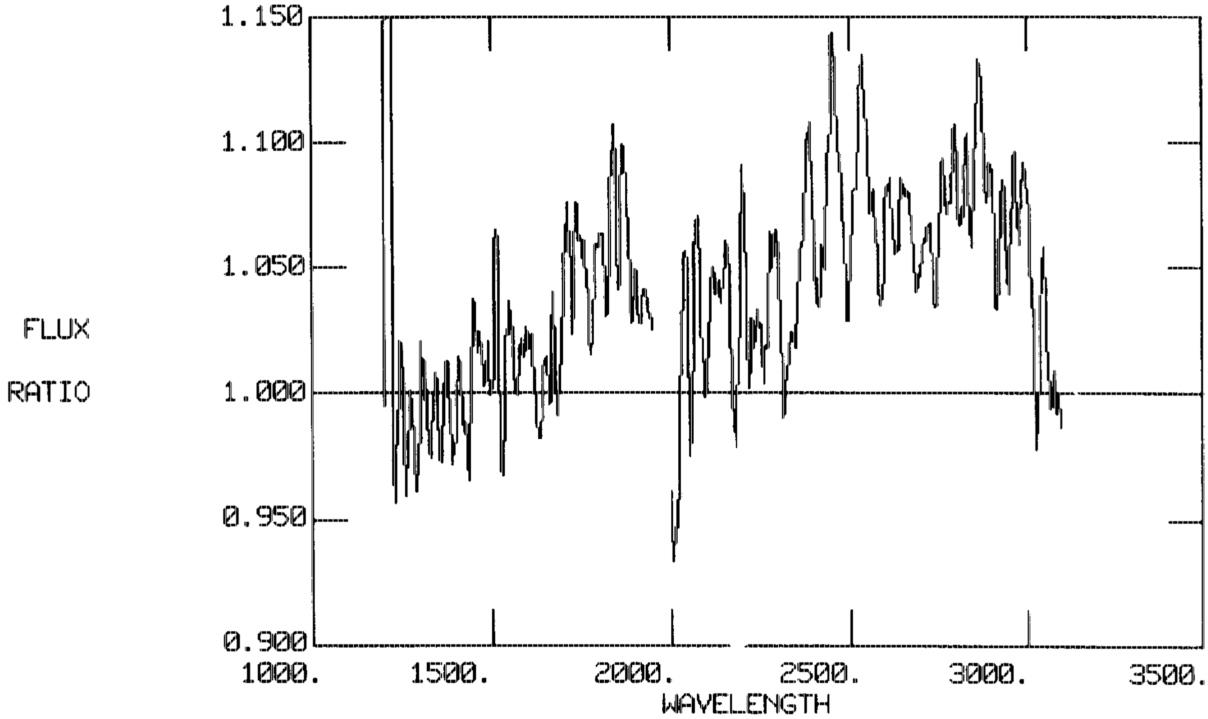

Figure 10. 30% / 100% Linearity Errors in Sept. 1982
SWP 18058 / SWP 18057
LWR 14188 / LWR 14191

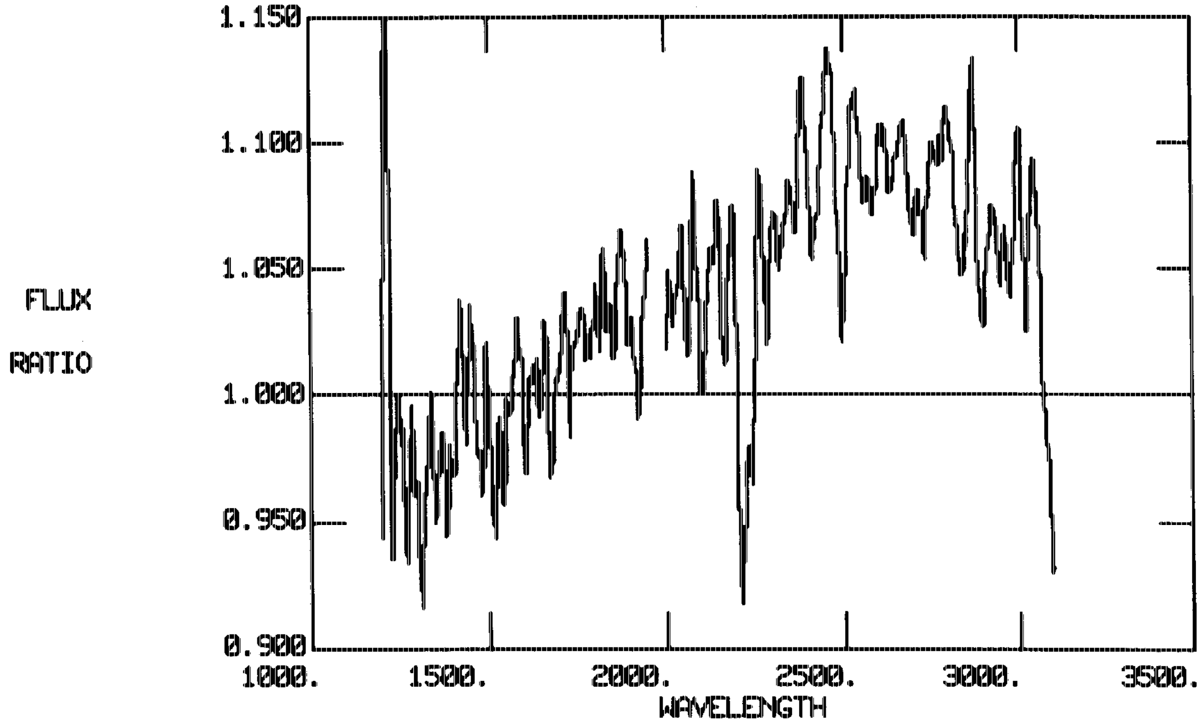

Figure 11. 30% / 100% Linearity Errors in March 1983
SWP 19410 / SWP 19409
((LWR 15554 + LWR 15560)/2) / LWR 15557

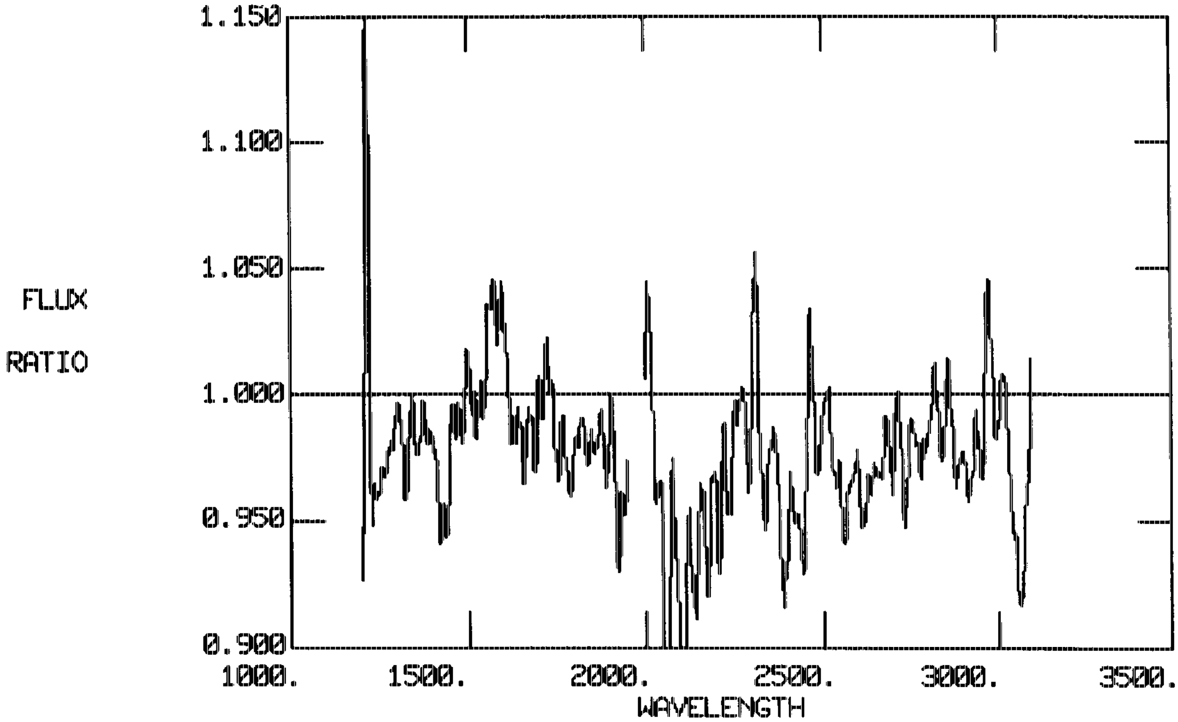

Figure 12. 60% (with moderate background) / 100%
Linearity Errors
SWP 16586 / SWP 16587
LWR 12822 / LWR 12823
March, 1982

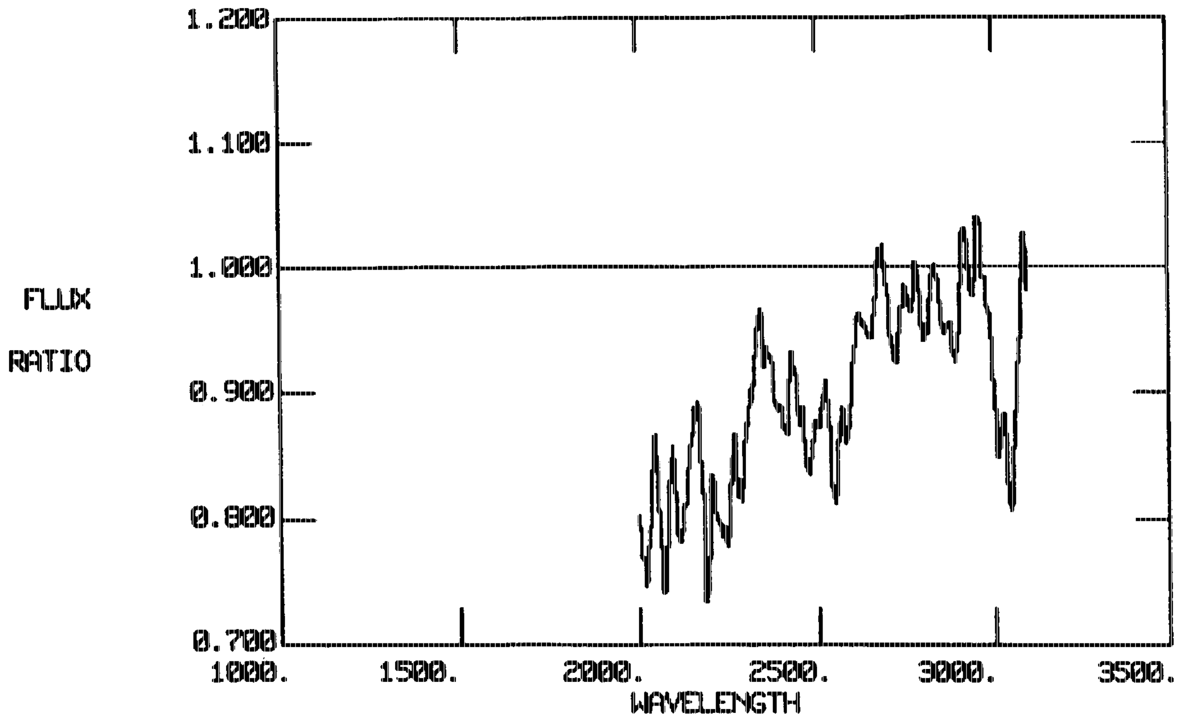

Figure 13. 71% Linearity Errors with High background
LWR 8218 / LWR 9984
July, 1980 / Feb, 1981