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 syrs 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 syrs. 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 5810 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 ratiosing.

(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.
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 SWF 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 nanometer bandpasses and are listed in Table 1. The binned flux ratios for the SWF show an rms deviation of 2.1% 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 0.5%/degree for the SWF 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 corresponding relative sensitivity factors are listed in Table 2. After correction for temperature induced sensitivity changes, the rms deviation for the SWF 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 SWF spectra and 3.8% for the LWR spectra. The reproducibility for trailed SWF 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 FNs, and for the LWR image was 35 DN or 5300 FNs. The average peak 'high' background level for the LWR was 95 DN or about 13200 FNs.

Non-optimum spectra with high backgrounds suffer from large linearity errors. As can be 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
BIMNED REPRODUCIBILITY ERRORS

<table>
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<tr>
<th>Central Wavelength</th>
<th>Figure 2a FR</th>
<th>Sigma</th>
<th>Figure 2b FR</th>
<th>Sigma</th>
<th>Figure 2c FR</th>
<th>Sigma</th>
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<td>.013</td>
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SWP mean dev = .0261 Not corrected for THBA sensitivity variation.
RMS dev = .0305

| Figure 2b: SWP 16582 / SWP 16587  
LWR 12818 / LWR 12823 |
|------------------------|----------------|

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

LWR mean dev = .0157 Not corrected for THBA sensitivity variation.
RMS dev = .0196

* Flux Ratios (FR) are binned into 100 angstrom band-passes
Table 2
Camera Temperature Changes and Sensitivity Ratios

<table>
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<th>Delta Temperature (Numerator - Denominator)</th>
<th>Relative Sensitivity Factors(%)</th>
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<tr>
<td></td>
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<tr>
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<td>-0.34</td>
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</table>

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

References

Schiffer, F.H. 1982, NASA IUE Newsletter, No. 13, p. 64.
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 2806 / 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

\( \frac{(LWR\ 9981 + LWR\ 9985)/2}{LWR\ 9984} \)

Figure 8. 30% / 100% Linearity Errors in December 1981

\( \frac{(LWR\ 12118 + LWR\ 12121)/2}{LWR\ 12117} \)
Figure 9. 30% / 100% Linearity Errors in March, 1982
SHP 16584 / SHP 16587
LWR 12819 / LWR 12823

Figure 10. 30% / 100% Linearity Errors in Sept. 1982
SHP 18058 / SHP 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 12022 / LWR 12023
March, 1982

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