

INTERNATIONAL ULTRAVIOLET EXPLORER

USERS' GUIDE FOR THE IUE LWP CAMERA

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1. INTRODUCTION

During the post-launch phase of IUE operations it was found that the images taken with the LWP camera could not be read reliably because of failures in the scan control logic. For this reason, the LWR camera was selected for the taking of all long wavelength spectra. The LWP camera was reoptimised at VILSPA during the summer of 1978 when read problems were rarely encountered. In addition, the procedures for using the camera were modified and only one incorrect read was experienced thereafter. Until recently the LWP camera has been read once per month only as a safety precaution.

On the basis of a comparison between two spectra taken by D Stickland, one from each long wavelength camera, which suggested there could be advantages in making the LWP camera available for observations, it was decided to make a preliminary study of the properties of the LWP camera. This has been completed and involved the taking of over 60 images, all read successfully. It seems reasonable to suppose that the read problem has been eliminated.

The study of the LWP camera was principally concerned with comparing the signal-to-noise performance and sensitivity of the camera with those of the LWR camera. The results were presented to the three-agency meeting of November 1980 and were sufficiently encouraging for a plan to be requested for the complete calibration of the camera. It was further decided there to release the camera for astronomical work from March 1981, subject to certain conditions (section 2).

This document describes the advantages and disadvantages of using this camera at this time, so that the user may decide whether he wishes to apply for permission to use it for a specific observation. The necessary plans for the full and accurate calibration of the camera are being prepared and will be presented to the next meeting of the three agencies (May 1981).

2. USE OF THE CAMERA

The study of the LWP camera required the construction of a rudimentary intensity transfer function (ITF) which was named ITFO, and the determination of the parameters for the geometric correction. These have been successfully used at the ground stations and in the UK for the geometric and photometric correction of LWP images. Most of the levels of ITFO are formed from single flat fields (most levels of the SWP and LWR ITFs currently used for data reduction are averages of four images) so that there is more 'noise' in the tables than in those for the other cameras. An improved ITF is planned as part of the overall calibration of the camera, but until this becomes available, ground station processing will use ITFO. The ground stations have no plans to reprocess with a better ITF images taken in the meantime, and so use of the camera for scientific purposes will at first be limited. An astronomer wishing to make use of the camera before the new ITF becomes available will therefore need to make a strong case to the ground station staff of his need to use it.

Use of the camera will at first be subject to the following constraints:

- 1) Each observer must obtain scientific approval of his need to use the LWP from the project prior to each shift.
- 2) The LWP may be switched on once and off once per observer per day.
- 3) The LWR will normally be switched off once the LWP camera has been switched on; this is to maintain a stable thermal environment.
- 4) Handover will normally take place with LWP off and LWR on, unless an extra camera switching can be avoided by leaving the LWP on for the next observer, who plans to use it.

5) The observer must clearly understand that the photometric accuracy of the data is less certain than data obtained from either the LWR or SWP cameras.

The data will initially not be absolutely calibrated but the camera is being included in the photometric calibration program so that a calibration will be eventually available.

3. A COMPARISON OF THE LONG WAVELENGTH CAMERAS

3.1. Sensitivity

When the LWP camera is used for astronomical work, it is clearly important that we be able to calculate 'optimum' exposure times. Since the ground station staffs have extensive experience with the LWR camera, it should be sufficient to calculate the ratio of the sensitivities of the two. Here we consider only low resolution, large aperture data.

What is sought, at a given wavelength, is the ratio of the exposure times for which two images of the same object, one from each camera, attain the same DN levels above the background. Here, provided we are on the approximately linear part of the ITFs, it does not matter whether the peak DN is meant, or some other representative value; either will in fact be proportional to the net integrated charge across the spectrum. Accordingly 'DN-spectra' were extracted from images which had been geometrically corrected, but not yet photometrically corrected. These spectra were remapped to a common wavelength grid ($\Delta\lambda=5\text{\AA}$) and then LWR spectra were divided by LWP spectra. The resulting quotient spectra were then averaged over 100Å bands. The pairs of images used here were (LWR image number first):

(7697, 1212),	(8304, 1218),	(8558, 1254)	BD+75 325
(8553, 1251),	(8758, 1256)		BD+28 4211

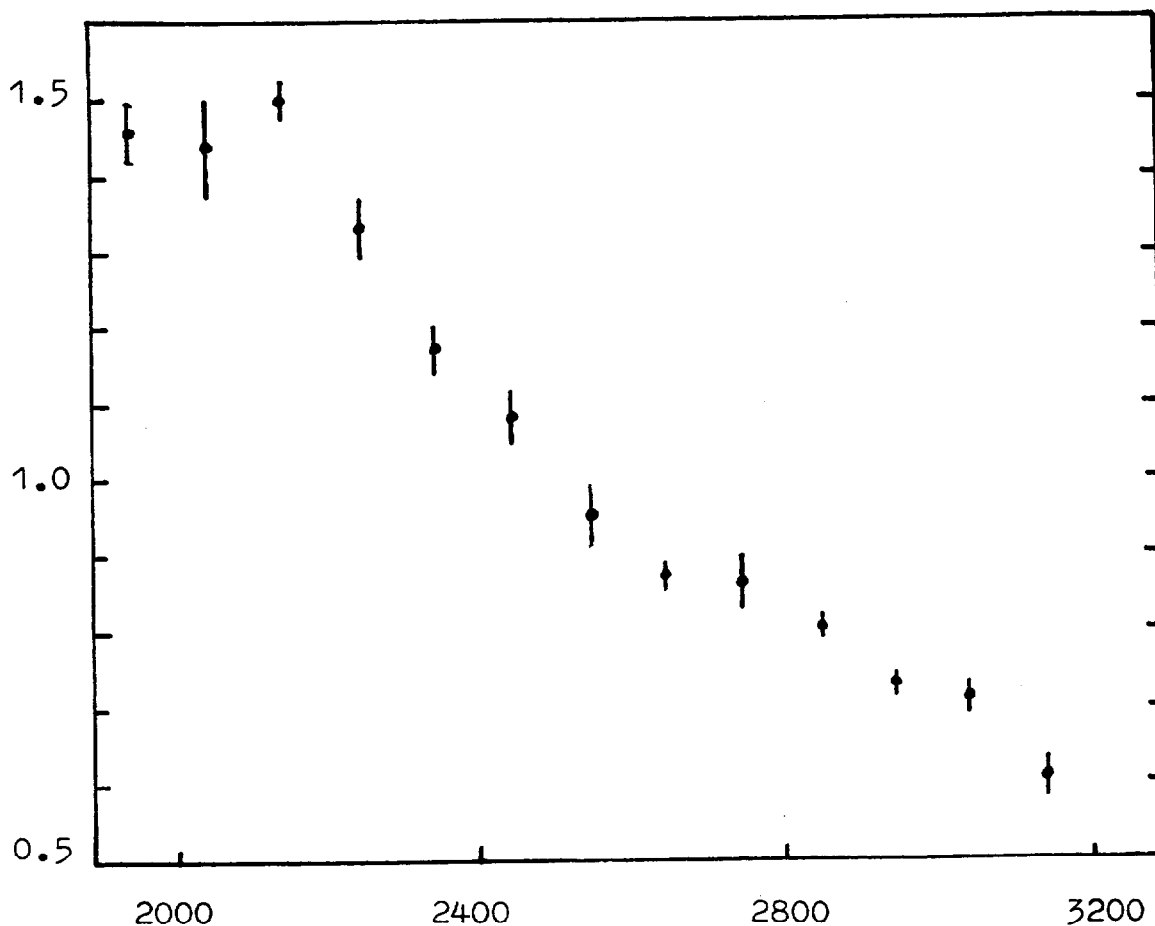
The quotients are multiplied by the appropriate ratio of actual exposure times for the pair concerned and the five sets of numbers averaged to produce the following table of relative sensitivity

(table 3.1, also fig 3.1). Here the sensitivity S_X of camera X is defined in unit of 'net integrated charge per second per spectral element', the 'spectral element' being the artificial slit used in the extraction (one slit per image line). The numbers in the third column of the table give standard deviations of each set of five numbers and appear as error bars in figure 3.1.

Table 3.1

Wavelength	S_{LWR}/S_{LWP}	
1900-2000	1.46	.04
2000-2100	1.44	.05
2100-2200	1.50	.02
2200-2300	1.33	.04
2300-2400	1.18	.02
2400-2500	1.09	.03
2500-2600	0.95	.03
2600-2700	0.88	.01
2700-2800	0.87	.02
2800-2900	0.81	.01
2900-3000	0.73	.01
3000-3100	0.72	.01
3100-3200	0.61	.03

Figure 3.1



Thus around 2150A it is necessary to expose the LWP camera for about 50% longer than the LWR to obtain similar DN counts above the background; the LWP camera is the more sensitive longward of about 2550A, at 2800A we need expose the LWP for only 85% of the corresponding LWR time.

3.2. Signal-to-Noise

Figure 3.2 compares the signal-to-noise performance of the two long wavelength cameras. The LWP spectrum was exposed for 20s, and the LWR for 24s. It is clear that even with the rudimentary ITFO and the reduced exposure time, the ratio of signal to noise in the LWP spectrum compares well to that in the LWR spectrum.

The graphs of signal to noise were obtained by least-squares fitting a second order polynomial to the continuum over sections of the spectrum. Reseaux and the HeII lines were omitted from the fit. The performance

Figure 3.2.

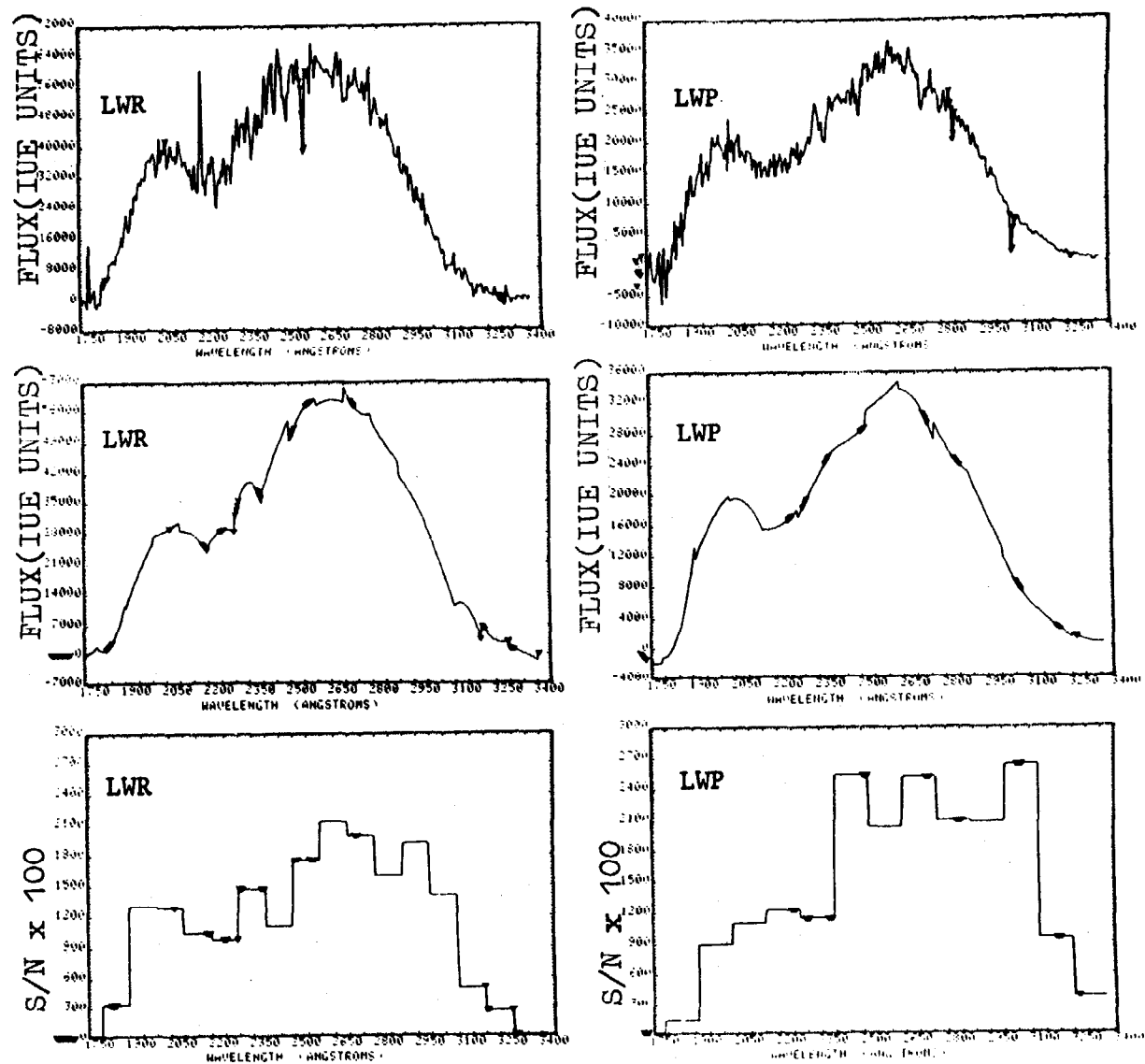


Figure 3.2. The method of determining the S/N ratios is illustrated. Two BD+75 325 spectra have been analysed showing the spectra, the 2nd order polynomials fitted to the continuum and the resulting distributions of signal to noise.

Figure 3.3.

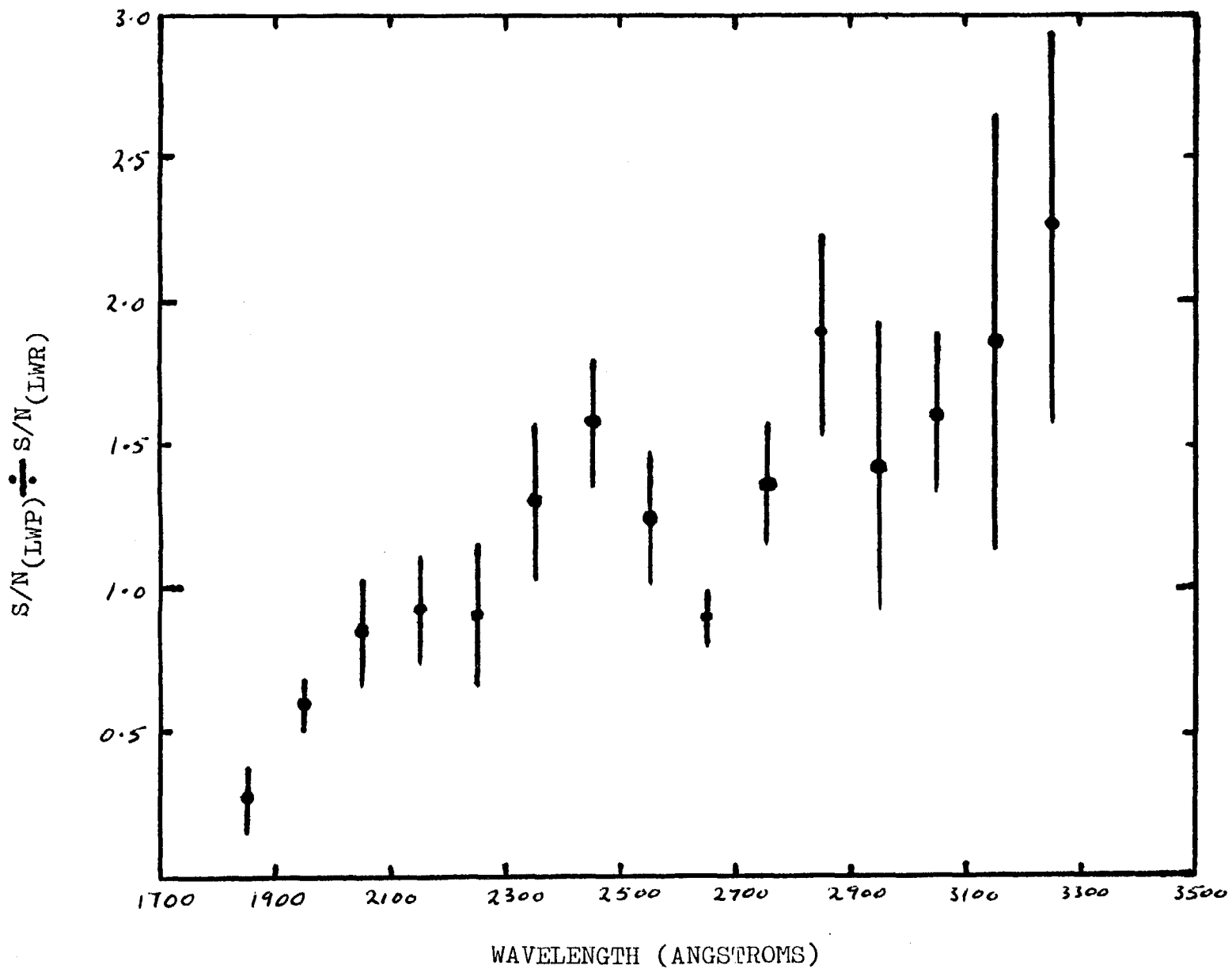


Figure 3.3 Plot showing the variation of the ratio of signal to noise in the LWP spectra to that in the LWR spectra. LWP exposure duration was 80% of LWR.

Figure 3.4.

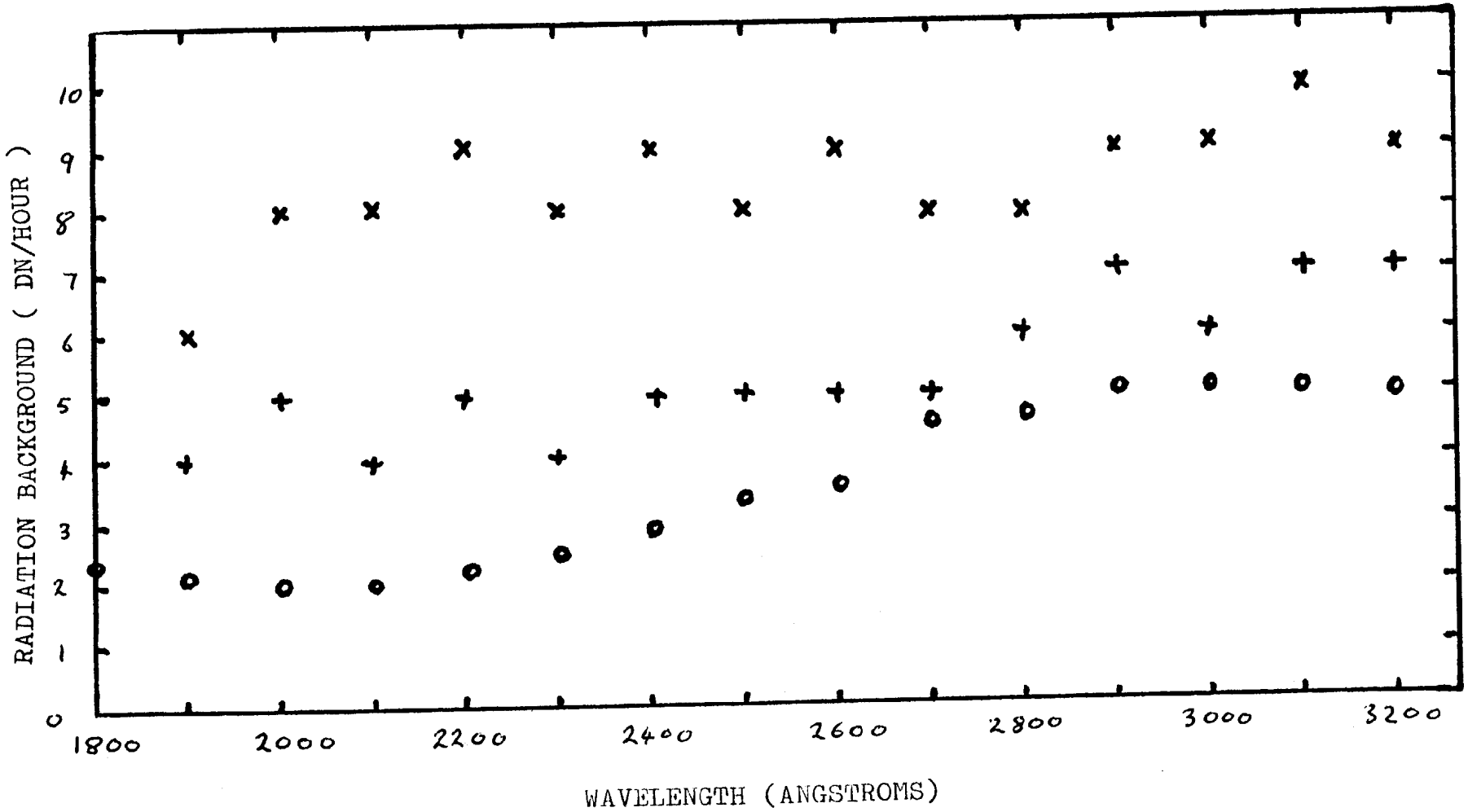


Figure 3.4 Graph showing the variation of the background accumulation rates. o, LWP1241 (radiation expose); x, LWR2982 (large aperture low resolution spectrum); +, LWR3974 (large aperture low resolution spectrum).

of the LWP camera is as good or better at wavelengths greater than 2400A, but is worse for shorter wavelengths. Figure 3.3 compares the averaged ratios of signal to noise from 7 LWP spectra to those from 5 LWR spectra over 100⁰ bands. In all cases, the LWP camera was exposed for 20% less time, so this would add to the advantage in using the LWP for faint sources and $\lambda > 2400A$.

3.3 Radiation Background

There is very little data available that can be used to examine this effect. Figure 3.4 compares mean DN values along the direction of the large aperture spectrum on the LWP and LWR cameras. The LWP image was a 'radiation expose', that is, an exposure during which the aperture was closed; whereas the LWR images were long exposure astronomical images. This made it necessary to use mean levels of the background about the LWR spectrum. Two LWR images were used and it is clear that the rate of accumulation of background DNs can vary significantly; nevertheless, the LWP appears to be less sensitive to radiation background. A similar conclusion was reached by D Stickland who compared a LWP radiation expose with the background in a LWR high resolution spectrum taken during the same shift.

3.4 Repeatability

Studies which involved taking ratios of spectra of the same star using the same camera (using the method outlined in section 3.1 for the sensitivity comparison) showed the cameras to be generally equivalent in this respect.

For example, both cameras gave results which were repeatable to 2-3% over 50 A bands.

3.5 Blemishes

The LWR camera produces a spike at around 2200 A - see Fig 3.2 - which generally contaminates the spectrum. For the LWP camera the relevant blemishes for low resolution spectra are listed in table 3.2.

Table.3.2. LWP: Blemishes affecting low resolution spectra.

Large Aperture

- ~1950 For image 1218 this lies entirely in the background slot, but may occasionally clip the edge of the spectrum.
- ~2610 Again, this lies in the background on 1218, but may sometimes overlap the spectrum.
- ~2840 This lies in the spectrum for LWP 11218, and given the kinds of wavelength shift experienced in the other cameras, it is likely that this reseau will affect observations of the MgI line at 2852.
- ~3065 Lies in the spectrum for 1218.
- ~3290 Lies in the background on LWP1218, but may sometimes lie in the spectrum.

Small Aperture

- ~2024 Reseau lies in centre of spectrum
- ~2265 This reseau lies about 6 pixels from the centre of the spectrum.
These are the only reseaux to affect small aperture data.

Two additional large blemishes (about 7 x 7 pixels) are present at line, sample coordinates of (319,213) and (417,207) on the GPHOT image. These will affect high resolution spectra only.

No microphonics have been observed on the LWP images. The LWR is often plagued with a narrow band of microphonics. However, a procedure to avoid this by using an extended heater warm up is being developed.

3.6 Comments on using the LWP camera for high resolution spectra. This report and the LWP study which preceded it are concerned with the use of the LWP camera for taking low resolution spectra. Only one high resolution spectrum has been taken and we therefore feel that we have insufficient data to give guidelines for the use of the LWP camera at this time. For instance, the LWR ripple function currently used in the extraction of high resolution LWP spectra needs to be re-optimised.

As of mid-March 1981, the VILSPA ground station was capable of processing LWP spectra in both modes. The Goddard ground station could process low resolution spectra only but expected to be able to process high resolution spectra in the near future.

However, a comment on the position as we find it may be of interest to some users and point the way to future work.

In order to compare the signal to noise in the two cameras, single image ITFs were constructed for each. These were used to correct flat field exposures of the same exposure level in each camera. Figure 3.5 shows the variation of the ratio of signal to noise across the targets of the two cameras. The images may therefore be compared. The positions of order 110, 99 and 81 are also shown; these orders have been extracted for the one spectrum we have and they are shown in Fig. 3.6. If one compares the perceived noise in the spectra of Fig. 3.6 with the variation of the signal to noise levels along the directions of the orders in Fig. 3.5 the two are seen to be related. This leads to a few qualitative results:

- 1) Those orders having numbers less than 81 should be generally less noisy on the LWP camera.
- 2) Those orders having numbers greater than 110 should be less noisy on the LWR camera.
- 3) For orders between 81 and 110 the location of the spectral feature of interest will determine which camera gives least noise.

Finally, the blemishes and reseaux marks will in general affect different wavelengths, so it should be possible to fill in affected wavelengths by using both cameras.

Figure 3.6.

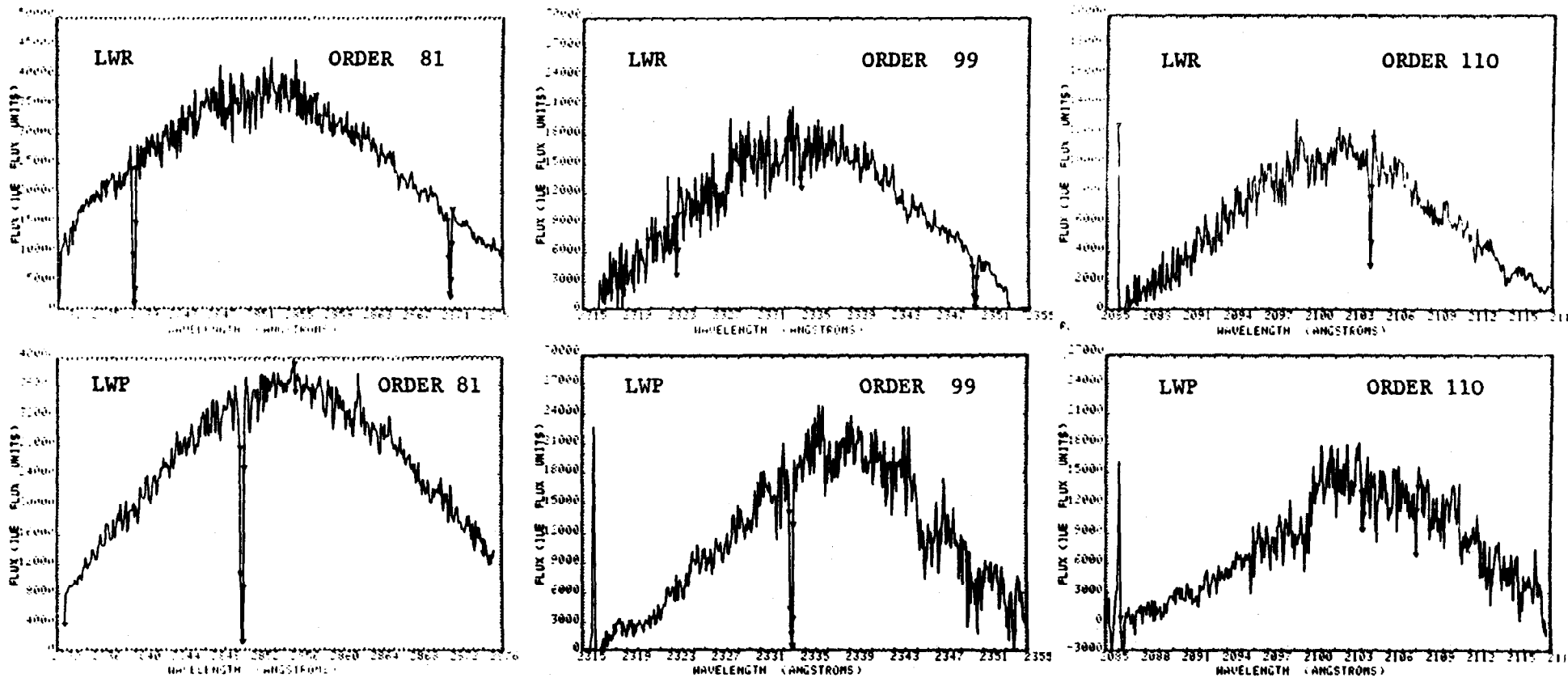


Figure 3.6 Extracted orders from the high resolution spectra.
Note the difference in the distribution of noise in the LWP and LWR Spectra.

4. THE PHOTOMETRIC ACCURACY OF ITFO

The LWP ITF currently at the ground stations (ITFO) includes images taken without precautions to compensate for the variability of the UV flood lamp. 'Effective exposure times' were defined for each level of the ITF, calculated to be consistent with the stated exposure times of certain of the images. The ITF curves thus obtained look reasonable, but because no attempt was made to calibrate the lamp output when the ITF flat fields were taken, the times may well be inaccurate.

To test the accuracy of ITFO, a set of four spectra (low resolution, large aperture) of the star BD+28 4211 was obtained with exposure times of 12 (LWP1267), 24 (LWP1265), 72 (LWP1266) and 96 (LWP1268) seconds respectively. After allowing for a camera 'switching-dead time' of 0.12 seconds (based on measured values for the LWR and SWP cameras), and the quantisation of exposure time by the OBC in units of 0.4096 seconds, the fluxes of the extracted spectra should be in the proportions:

1 : 2.01 : 6.09 : 8.14

The images were processed with ITFO and the four spectra extracted. 'Quotient spectra' were then formed by dividing each element in a given spectrum by the corresponding point in another (giving six quotient spectra in all).

When we take the average of all points in the quotient spectrum between 2000 and 3000 A, we obtain the following table of flux ratios:

Table 4.1

	Observed Flux Ratio	Expected Flux Ratio	% Error
1265:1266	.318	.332	4.2
1267:1266	.156	.164	4.9
1267:1265	.486	.497	2.2
1265:1268	.232	.248	6.5
1266:1268	.733	.748	2.0
1267:1268	.113	.123	8.1

The first column gives the observed average between 2000A and 3000A while the second column gives the expected value based on the exposure times of the images. The final column gives the relative error, expressed as a percentage ($=100 \times \text{absolute value} (1 - \text{first column} + \text{second column})$).

The numbers in this table should be compared to those in Table 4.2. These are the averages between 2000 and 3000A of four LWR images of the star BD+75 325 (LWR4284-7), which have exposure times of 12, 24, 36 and 48 seconds respectively.

Table 4.2

	Observed Flux Ratio	Expected Flux Ratio	% Error
4284:4285	.513	.495	3.5
4284:4286	.347	.331	4.6
4284:4287	.263	.246	6.5
4285:4286	.678	.669	1.3
4285:4287	.513	.497	3.2
4286:4287	.756	.743	1.7

Over this range, therefore, the 'linearity' of ITFO and of the LWR ITF are broadly comparable. One difference is that in the LWR the longer of two exposures always has less flux than would be expected from the flux of the lower and the ratio of exposure times, whereas the reverse is the case for LWP.

In figure 4.1 we plot the quantity x (= flux ratio divided by the ratio of exposure times) against the ratio of exposure times. All points above the line $x = 1$ are from pairs of LWR images, whilst all those below are from LWP images. As the ratio of exposure times departs from unity there is a clear tendency for the linearity 'errors' to increase, though in opposite senses for the two cameras.

The quotient spectra were also averaged over 100A bands. Figure 4.2 shows the results for the pairs (LWP 1266/LWP 1265) and (LWR 4286/LWR 4284); each pair has an expected flux ratio of about 3. Again, the performance of the ITFs of the long wavelength cameras is broadly comparable.

Figure 4.1 Figure showing the extent of non-linear photometry in the LWR (⊗) and LWP (x) ITFs. A value of 1.0 represents linear photometry.

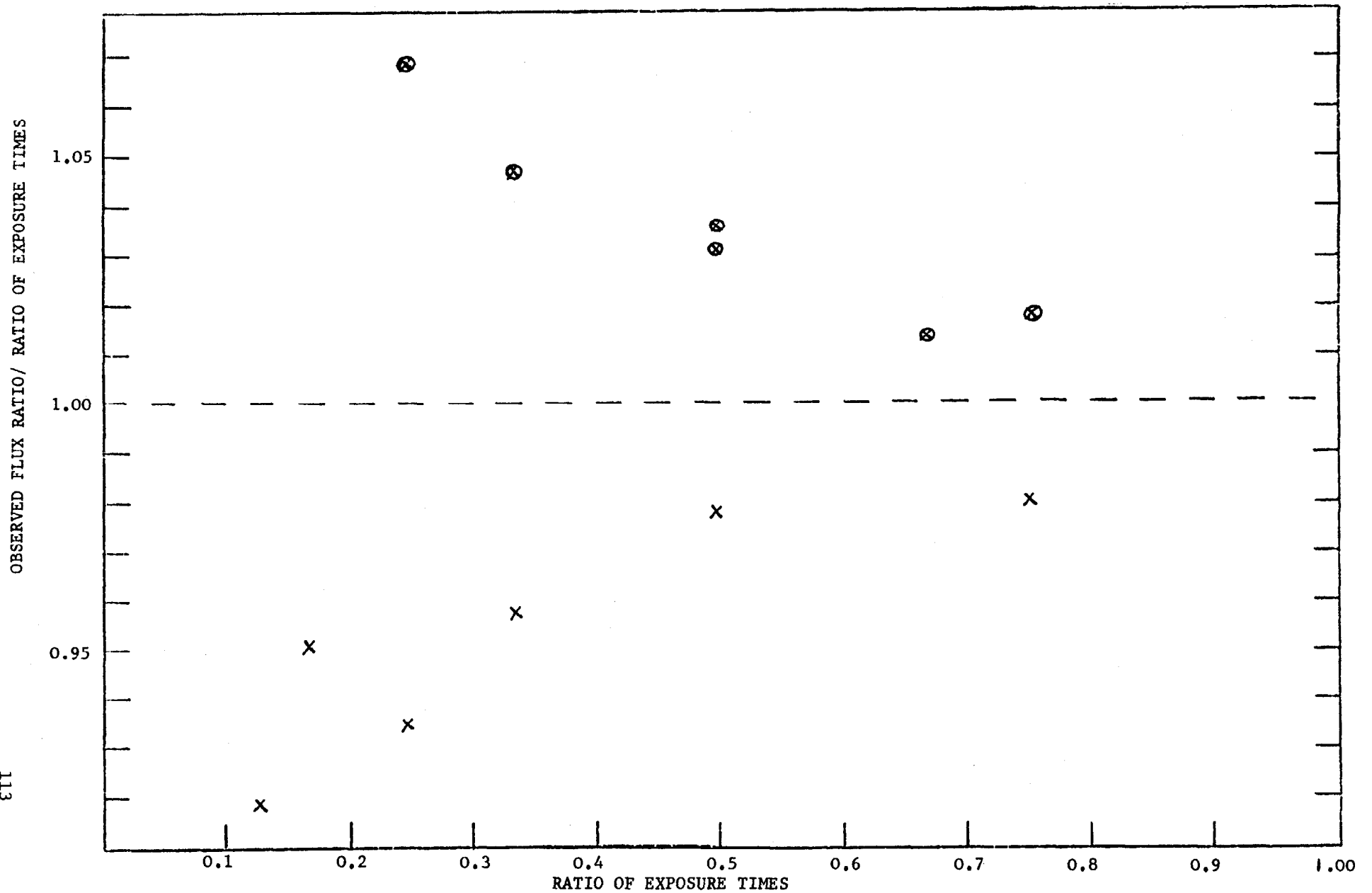


FIGURE 4.2

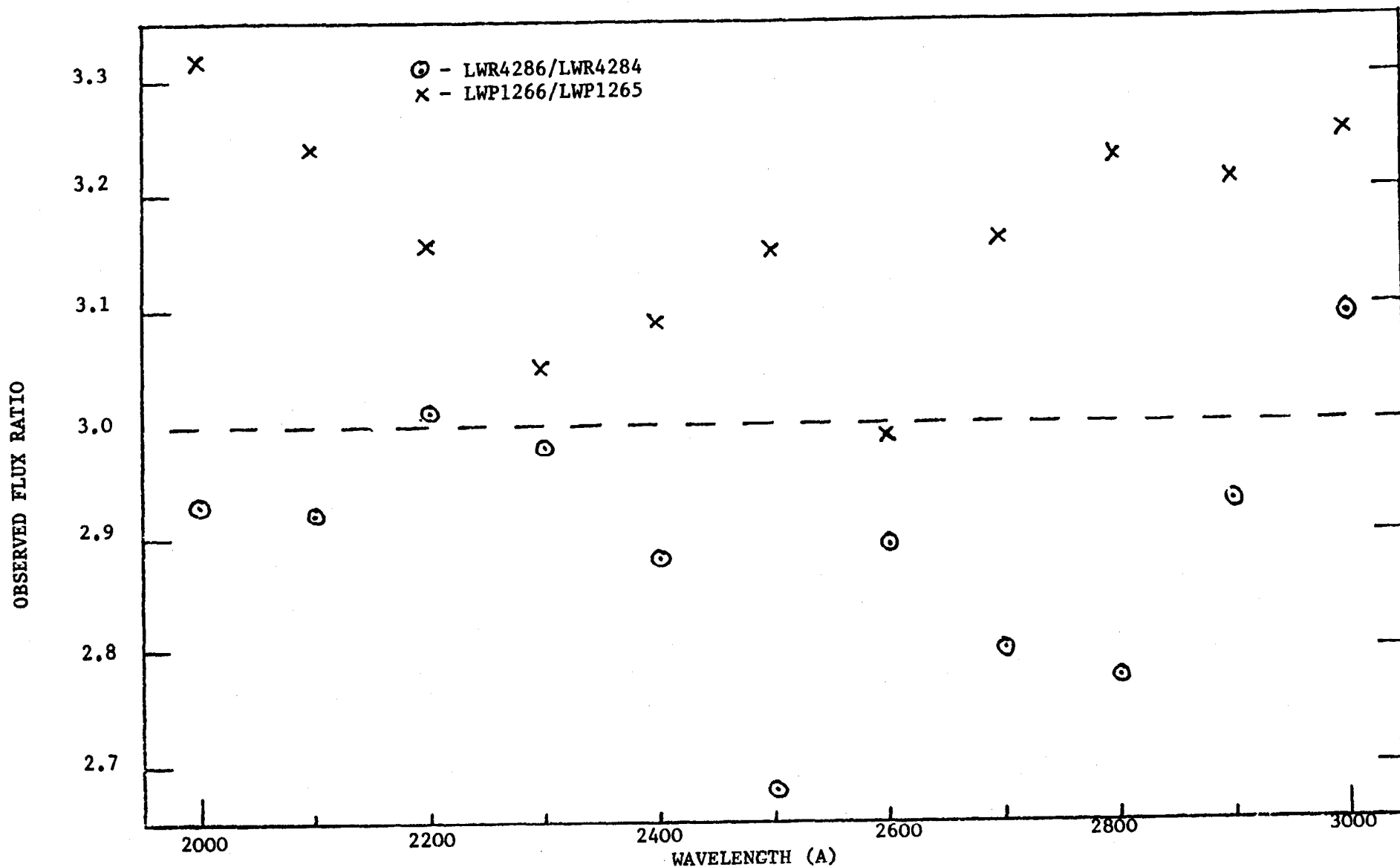


Figure 4.2 Figure showing the variation of the ratios of fluxes with wavelength for two spectra whose exposure times have a ratio of 3.0. Hence, a value of 3.0 represents linear photometry.

Thus, while ITFO is not as accurate as we would like, it is nevertheless as good as could be expected, and does not suffer by comparison with the LWR ITF. (It should here be mentioned that the FNs of the LWR ITF are under review in the hope of making the LWR system 'more linear').