Notification of an Error in the Photometric Correction of SWP Images

In late June, 1979, it was discovered that all of the SWP images processed after May 22, 1978, had been photometrically corrected with an Intensity Transfer Function (ITF) whose third level was composed of DN values which were 3/4 of the correct values. Following this discovery, the IUE staff developed and tested an improved ITF. The new SWP ITF has been used for routine image processing since July 7, 1979. On July 16, a letter was sent to all of NASA's principal investigators for IUE observing programs to alert them to the likelihood of photometric errors in their spectra. On September 24, a second letter was sent to the principal investigators to advise them of the progress that was being made towards an algorithm for correcting their spectra. Copies of these two letters are being reproduced here so that they will be available to anyone with an interest in the IUE data.

Several trial correction algorithms have been tested, none of which has been completely satisfactory. At the present, an improved algorithm is being tested. This algorithm should correct the spectra processed with the bad ITF with higher accuracy than the reproducibility of the system. It is expected that a letter describing a correction algorithm, at least for low dispersion spectra, will be mailed to the principal investigators in November 1979. Following that, articles describing the correction algorithm, the new absolute calibration for the SWP spectra, and the photometric accuracy of IUE spectra will be published in the IUE Newsletter.

Albert Holm
22 October 1979

July 16, 1979

To: IUE Guest Observers

From: Dr. Albert V. Holm, IUE Resident Astronomer

Subject: An Alert to IUE Users Regarding an Error in the SWP Photometric Correction

1. The Problem. IUE personnel have discovered that a serious error exists in the photometric correction of all SWP images processed between May 22, 1978 and July 7, 1979. The photometric correction of IUE images is accomplished by an intensity Transfer Function (ITF) which is essentially the DN levels measured during a graded series of Hg flood lamp exposures. The photometric error was caused by the inadvertent averaging of a blank image with three good flood lamp images during the construction of one level of the ITF. The consequence of this error is that in the "middle" exposure levels a pixel will be assigned a Flux Number (FN) that is too large. All spectra will be affected to some extent by this error, but spectra that have high backgrounds or that are underexposed will be most severely affected. In a high background image the background may be erroneously high so that the net spectrum will be lower than it should be. Conversely the pixels in an underexposed spectrum will be given too large FN so that the net spectrum and the fluxes derived from it will be too large. High dispersion spectra will probably also be affected since they tend to have a significant background caused by halation and scattered light. Equivalent widths and central depths of lines may also be erroneous in both high and low dispersion spectra.

2. The Magnitude of the Error. Detailed, quantitative studies of the photometric consequences of this error are being conducted. It is known that pixels having FN less than 1084 or greater than 4291 will be reasonably photometrically accurate. The maximum error occurs for those pixels having a FN of 2141; the error for those pixels will be 63 percent. The photometric properties of the extracted spectra depend on the errors of the individual pixels in a complicated manner because the light level decreases perpendicular to the dispersion on a scale of several pixels. As a result of this point spread function every sample of the extracted spectrum includes pixels with several different FN levels. Preliminary indications are that normally exposed spectra of O and B stars (or sources having a similar energy distribution) on low background images will be accurate to about 10 percent or better. Spectra taken on high background images have been found to be deficient by up to 50 percent. Conceivably an underexposed spectrum superimposed on a high background could be up to 63 percent high. The background spectrum will have photometric errors if the integrated Flux Numbers are in the range of 18,428 to 72,947 for low dispersion, point-source spectra, of 31,436 to 124,439 for low dispersion, extended-source spectra, or of 9,756 to 38,619 for high dispersion, point-source spectra. Underexposed spectra on a low background image may have deviations of 10 to 20 percent.

3. <u>The Correction.</u> A corrected ITF has been generated and is now being used at GSFC to process all SWP images since July 7, 1979, at 19:40 GMT. Which ITF was used to process a given image can be determined by inspection of the IUESIPS label for that image. Images with times of processing in the label occurring after·the above time will have been processed with the new ITF. A further check can be made by inspecting the values in an array inserted into the label for the geometrically and photometrically corrected images. For the incorrect ITF these constants are:

0	1753	3461	6936	9000	10575
14299	17709	21546	25156	28674	

For the new ITF these constants are:

0	1684	3374	6873	9091	10586
14371	17745	21524	25105	28500	

4. <u>Correction of Old Data.</u> An algorithm for the correction of spectra processed using the incorrect ITF is being studied. Results of this study and of the study of the photometric consequences of the error will be described soon in issues of the IUE Newsletter.

5. <u>The Calibration.</u> Spectra processed with the new ITF will require a sensitivity calibration different from that published by Bohlin and Snijders (1978, IUE Newsletter No. 2). Preliminary indications are that minimal changes will be required at 1300 $\overset{o}{A}$ but that the change at wavelengths longer than 1600 $\overset{o}{A}$ will be on the order of 20 percent. A new calibration curve is being derived and will be published in a future issue of the IUE Newsletter.

September 24, 1979

TO: IUE Guest Observers

FROM   Albert V. Holm, IUE Resident Astronomer

SUBJECT: An Update on the SWP ITF Problem

1. The Magnitude of the Error In Spectra Processed With The Old ITF. In July
    an alert was sent to all IUE Guest Observers describing an error which was
    discovered in the SWP Intensity Transfer Function (ITF). Some spectra
    processed with the old ITF, particularly well-exposed ones with either
    very low or very high backgrounds, are not affected significantly by the
    ITF error. Figure 1 provides a crude means of estimating the photometric
    error that may exist in any point source spectrum due to processing with
    the old ITF. The figure shows a relationship between net fluxes derived
    with the incorrect ITF and net fluxes with the new ITF (see Section 3) for
    four different levels of background. These relationships are estimated by
    a correction algorithm which is not sufficiently accurate to correct data
    having large errors but can give an estimate of where large errors exist.
    To decide which curve to use in evaluating your data, you must determine
    the FN/pixel for the background spectrum. The background spectrum on your
    data tapes and plots are normalized to the effective area of the
    extraction slit used for the source spectrum. To find the background
    level per pixel, simply divide the background spectrum by this effective
    area. For high dispersion spectra, the area is 9 pixels (HT=5), for point
    source and small aperture low dispersion spectra, it is 17 pixels (HT=9).
    For extended source spectra, the area is 29 pixels (HT=15). If the
    background FN/pixel exceeds 4291 there should be no errors due to this ITF
    problem.

    A crude evaluation of the accuracy of spectra of extended sources which
    fill the large aperture uniformly can be made by dividing the net spectrum
    by $\sim$20 (the pixel area for a slit $\sqrt{x}$ pixels wide extending the length of
    the large aperture), and adding the background FN/pixel. This arithmetic
    will give an approximation to the FN/pixel for the source. The error in
    both the source FN/pixel and the background FN/pixel can be estimated from
    Table 1. Here, the "% error" is defined by $(FN_{old} / FN_{new})-1 = \%$
    error.

    The error in the net flux can be estimated by subtracting

Table 1 - Percentage Error as a Function of Old FN/Pixel

Old FN/pixel	% Error
1080	4%
1500	30%
2141	63%
2500	41%
2750	31%
3000	23%
3500	11%
4290	1%

    the error in the background from that of the source.

The SWP absolute flux calibration in low dispersion will be appropriate for many of the spectra even though there is a linearity problem. The SWP calibration for absolute fluxes was derived from observations of stars for which the background was negligible.. The net flux numbers for the calibration stars were in the range of 50,000 to 70,000 at 1300 Å, 24,000 to 32,000 at 1500 Å, and 20,000 to 40,000 at 1800 Å. Spectra having FN which differ from the FN associated with the spectra from which the calibration was derived will require some correction.

Two Guest Observers volunteered to evaluate the effects of the ITF error on high dispersion absorption line spectra. For each, one high-dispersion spectrum was reprocessed with the corrected ITF. Dr. D. Leckrone studied an optimumly-exposed, low-background spectrum of a late B type star having many sharp lines of weak to medium strength. He found errors in the line residual intensities and equivalent widths that were on the order of 25%, but which varied from line to line depending on strength and location along the order. His conclusion was that spectra processed with the old ITF were inadequate for his project. Dr. B. Savage studied a high-background spectrum of an LMC O type star which was observed to investigate the interstellar medium. Savage found that the net spectra in the two reductions differed by a factor of about 40% which varied from order to order, but that the profiles and equivalent widths in the normalized spectra were nearly identical. In fact, he had greater agreement between the line parameters derived from spectra processed with the two ITF's than he did with a later observation of the same star that was processed with the correct ITF. His conclusion was that, for his spectra, the old ITF appeared to give satisfactory results.

2. Progress Toward a Correction Algorithm. An accurate correction algorithm must consider what the incorrect processing did to individual pixels, but for use by the Guest Observers it must be applied to the net or gross extracted spectra or to the line-by-line spatially resolved spectra supplied for low dispersion. A multiplicative or additive correction to the extracted samples of the gross spectrum is likely to introduce additional errors into at least some subset of the data. For example, a given FN value of the extracted sample might be from a high background, weakly exposed spectrum or from a low background, well exposed spectrum. To assign a single correction to both would be to degrade the data of one or the other Guest Observer. Similarly, even the samples in the low-dispersion, line-by-line spectra represent parts of five different pixels. Therefore, the correction needed will depend upon whether the sample was extracted from pixels of the same exposure level at the top of a widened spectrum or from pixels along the steeply sloping region along the side of the spectrum.

Because of the considerations given above, we have been working on ways to deconvolve an extracted sample into a reasonably accurate representation of the original pixel values. For the net extracted point source spectra, we have been using the finding of Koornneef and de Boer (1979, IUE Newsletter No. 5) that the spectrum has a Gaussian profile. Figure 2 shows an example of the errors in a low dispersion spectrum that was corrected with such a scheme. In this figure, the net spectrum from the correctly processed (new ITF) image was divided by the net spectrum derived by correcting the old ITF processing. The figure shows both high frequency errors of about 5% and some systematic errors of ±5%. In the past few days we have tried a scheme which uses a spectrum width that varies with wavelength (Koornneef, 1979, private communication). This reduced the systematic error and we intend to try the scheme on more spectra. A scheme to decompose the line-by-line samples is conceptually simpler and probably more accurate but has not yet been tested because we have been trying those schemes first which require the least computing. We intend to test the correction of line-by-line spectra in the near future. Our hope is to have a working scheme that can be used by everyone within a month.

3. **The Quality of Spectra Processed With the New ITF.** The quality of the photometry is improved significantly by processing with the new SWP ITF which has been used on all SWP data processed since July 7, 1979, but some photometric errors may still be present in the data for both cameras. Figure 3 illustrates the magnitude of error for three spectra after processing with both the old, incorrect ITF and the new ITF. All three of these spectra were badly processed in the old system because of high background levels or low signal levels. The amount of error is determined by dividing the measured flux/second for the test spectrum by the flux/second for a normal spectrum of the same star. The normal spectra are exposed so that the DN level at the most intense part of the spectrum is about 200 DN. Each spectrum was binned into 25 Å bins before the division was done. The top portion of the figure shows the errors in a spectrum of a standard star that was added to a tungsten flood lamp image in a double exposure to simulate high radiation levels. The star was BD+28°4211 with spectral type sdO. With old ITF processing, the photometric errors in the net spectrum ranged from -12% to -50% (if the points at 1950 Å and 1975 Å near the target rings are ignored). When the two spectra forming this ratio were reprocessed with the new ITF, the errors were reduced to a maximum of 24% in the same interval. The middle portion of the figure shows the errors in a spectrum that was exposed only 50% as long as the normal spectrum for the same star. The star was BD+33°2642 with spectral type B2. With old ITF processing, the errors ranged from +12% to -18%. After reprocessing the rms errors were greatly reduced, but a systematic deviation of the slope by a few percent or more

over the wavelength interval of the SWP is suggested. The bottom of the
figure shows the errors in a trailed spectrum that was exposed to 30% of
the level of a normal trailed spectrum of the same star. The star was
HD 60753 with spectral type B3. With old ITF processing the errors were
as large as 48%. The errors in the trailed spectra more accurately mirror
the errors in the FN values per pixel than do the errors in point source
spectra because in trailed spectra most of the pixels in an extracted data
point have the same exposure level. Spectra of extended sources will have
similar behavior. The errors in the reprocessed spectra are dramatically
less, but there is a systematic slope error present in this ratio also.
The sources of the remaining errors are being investigated on a continuing
basis.

4. **An Additional Problem Arising in the Photometric Correction Process.**
While working with the ITF problem, I discovered that the present ITF does
not extend to all levels to which the cameras can be exposed.
Furthermore, the present image processing software system truncates pixels
which exceed the highest ITF level to that level. Hence, overexposed
images will have an aditional source of photometric error. Table 2 gives
approximate averaged DN values for the highest non-saturated ITF levels in
the vicinity of the low dispersion spectra.

Table 2

Approximate Highest DN Values In The ITF

SWP		LWR	
λ	DN	λ	DN
1200	197	2100	250
1300	216	2300	245
1400	235	2500	240
1500	245	2700	225
1600	243*	2900	220
1700	239*	3100	190
1800	228*	3300	180
1900	242*		

* higher levels exist which may include
  saturated pixels.

These values were determined from printed averages of 12x12 pixels. The
image processing group will be extracting spectra from the ITF images in
order to permit us to more accurately advise you on the limits. In
addition, the software system will be revised to extrapolate beyond the
top ITF level. Extrapolated pixels will eventually be flagged. Work is
in progress to add higher levels to the ITF.

5. <u>Request For Feedback</u>. To decide where to use the available manpower to derive a correction algorithm that will be of greatest use to the most people, it would be useful to receive some feedback from the Guest Observers. Specific information that would be of use include:

     o   the number of spectra you need to correct

     o   the size of errors in flux that you could tolerate

     o   the amount of assistance you need in applying a correction to the net or gross extracted spectra; to the line-by-line extracted spectra

     o   whether you can use corrected data in a digital format (on tape) or need a Calcomp plot

     o   whether you have made any studies of the data you have received that may assist us in deriving a correction algorithm. Such studies include determinations of point spread functions.
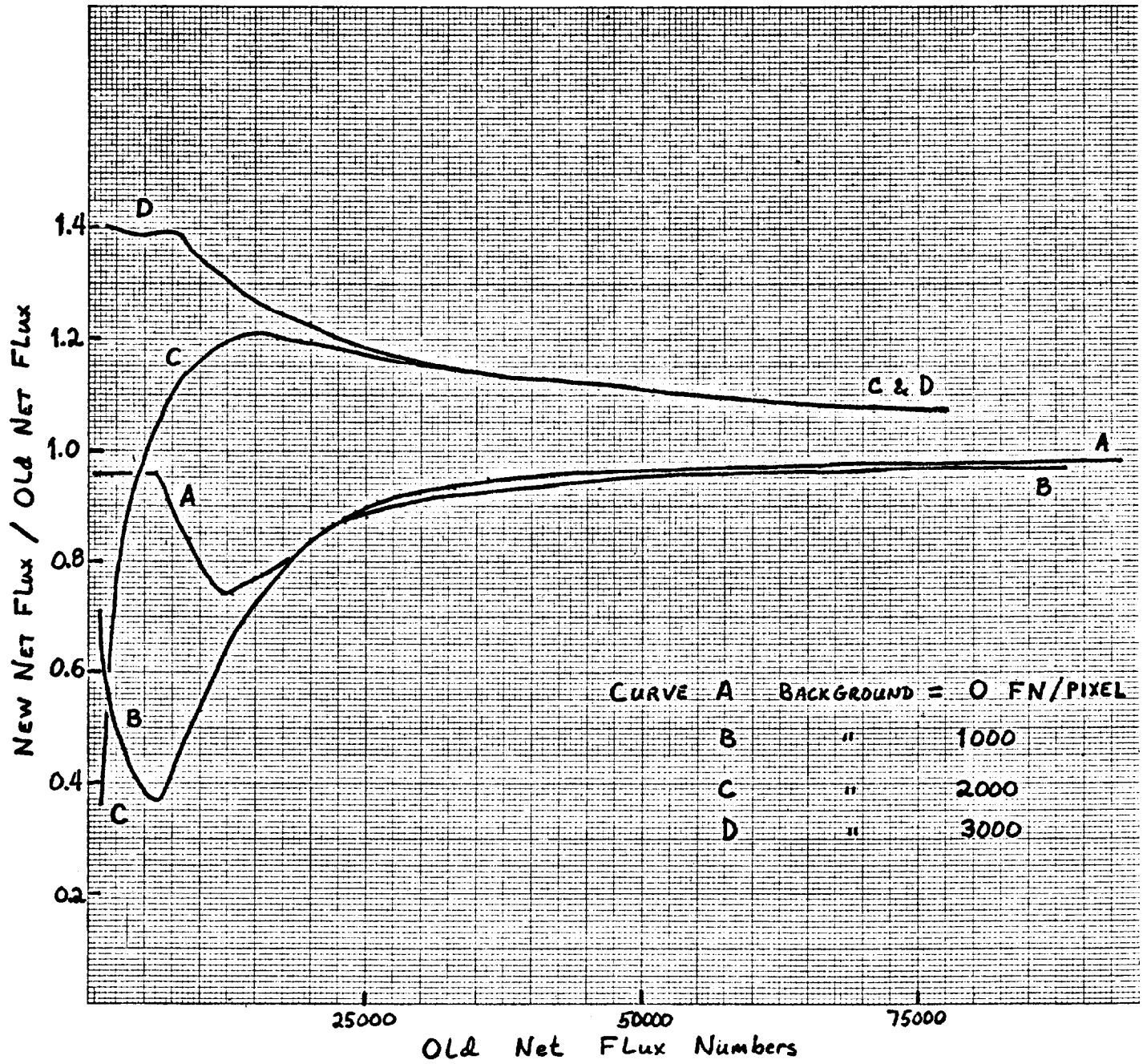
A questionnaire is attached for your convenience. Please give us any additional comments that might help us to understand your needs.

Barry E. Turnrose for *Albert V. Holm*

Albert V. Holm
IUE Resident Astronomer

Attachment

FIG. 1
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Curve A Background = 0 FN/PIXEL
     B   "   1000
     C   "   2000
     D   "   3000

Old Net Flux Numbers

New Net Flux / Old Net Flux

SWP 4006,BD+33 2642,LO DISP,LG AP,2M,DAY23,SCHIFFER,FNCAL
ORDER 1   NEW / OLD CORRECTED < 02 CORRECTION

Exposure level for this spectrum
was 50% of a normal optimumly-
exposed spectrum.

RATIO OF "NEW ITF" NET SPECTRUM TO *CORRECTED*
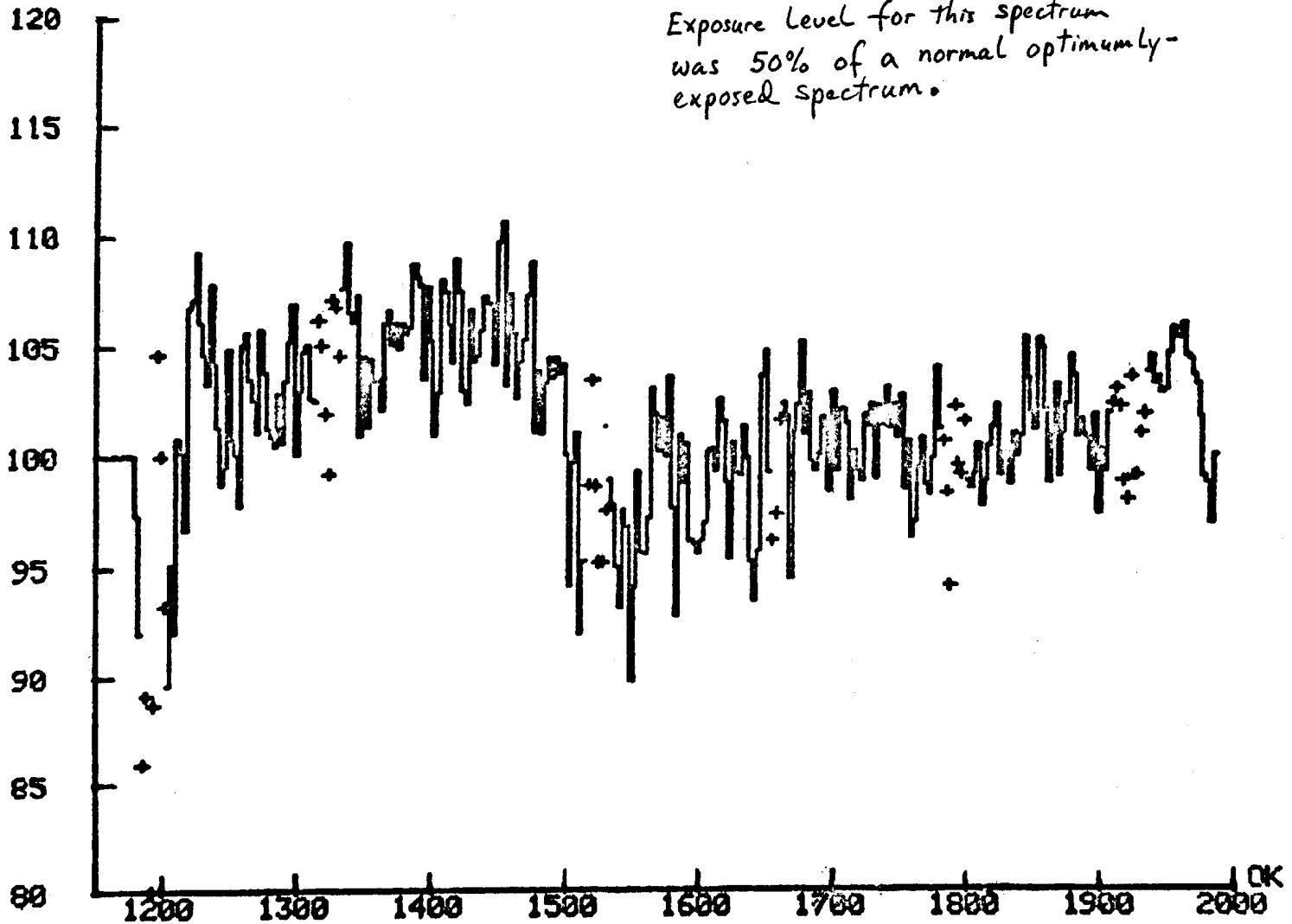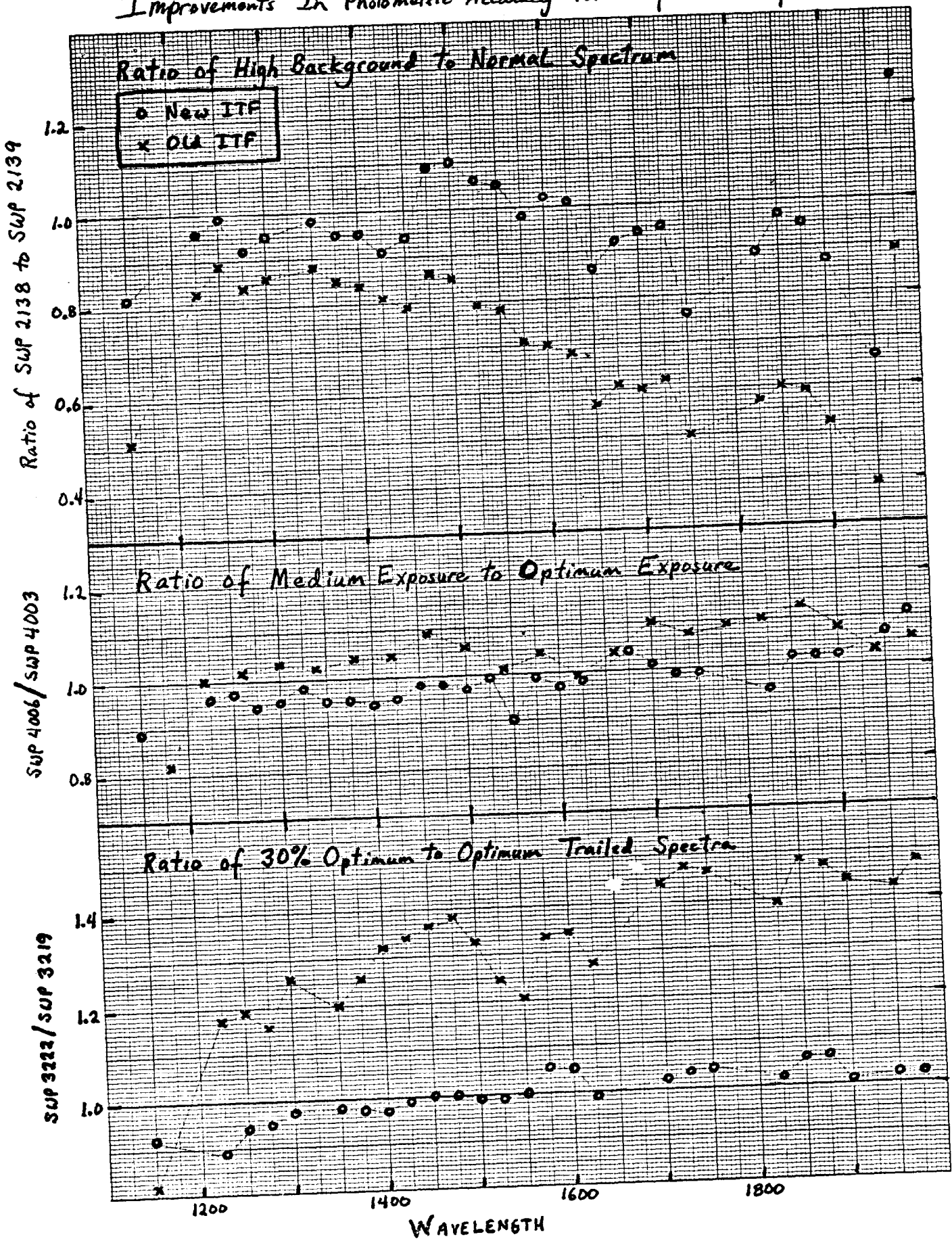"OLD ITF" NET SPECTRUM, EXPRESSED AS A PERCENT.

Fig. 2

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FIG. 3

Improvements In Photometric Accuracy For Re-processed Spectra

Please fill out the following questionnaire and return to Donald K. West, IUE Observatory Administrator, Code 685, Goddard Space Flight Center. The Questionnaire is intended to help the IUE Project assess the needs and capabilities of observers in correcting for the SWP ITF error and also in examining and analyzing data stored on their tapes.

How many spectra do you need to correct for SWP ITF errors?_____

What size errors in flux can you tolerate?_____

What assistance would you need in applying a linear correction to the net or gross extracted spectra? To the line-by-line extracted spectra?

Can you use the corrected data on magnetic tape or do you need a Calcomp plot? _____

Do you have data on point spread functions or other parameters that may help us derive a correction algorithm? If so, use the back of questionnaire.

Have you accessed data on the G.O. tape (Yes, No)_____
    If not, why not (too hard, no facilities, other?)_____

What computer facilities do you have?
    Computer (e.g. IBM 360, PDP 11/34)_____
    Operating system (e.g. OS, RSX11M _____
    Software languages (e.g. FORTRAN, FORTH)_____
    Peripherals (e.g. CALCOMP plotter, terminals in use)_____

Do you have a working program that reads your G.O. tape, scales, and plots the data?_____

    If yes, what kind of plot is made (e.g. CALCOMP, TEKTRONIX)

What other types of programs have you developed to examine and analyze IUE data?_____

Would you be willing to share your programs with other IUE observers?

Would you be willing to allow others to use your facilities to reduce IUE data? _____

How would you classify your preferences as a user of IUE data?

Prefer to process data at own facility with own data_____

_____
_____

Prefer to process data at own facility but would appreciate
receiving computer programs to help examine and analyze IUE data

_____
_____

Prefer to process data at some regional facility_____

_____
_____

COMMENTS:

_____
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