CSC/TM-82/6207

DATA ANALYSIS PROCEDURES FOR THE INTERNATIONAL ULTRAVIOLET EXPLORER REGIONAL DATA ANALYSIS FACILITIES

PART I: GUIDELINES FOR DETERMINING THE WAVELENGTHS AND FLUXES FROM EXTRACTED SPECTRA

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ABSTRACT

The reduction of data from the International Ultraviolet Explorer (IUE) is a complicated and involved process. Fortunately, the majority of the reduction process is performed by the International Ultraviolet Explorer Spectral Image Processing System (IUESIPS). However, since this system is designed to reduce all of the IUE data, the accuracy of the results can be improved by tailored processing for each specific observation. This document addresses the limitations imposed by the IUESIPS design which can be improved by tailored processing beyond that done by IUESIPS. Three areas are discussed: Wavelengths, fluxes, and signal-to-noise ratios. In each area, a method for analyzing the IUESIPS processing is presented; factors which effect the accuracy are discussed; methods for correcting common problems are derived; and the accuracy limitations of IUE data are addressed.

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SECTION 1 - INTRODUCTION

This document is a guide to reducing IUE data to obtain the best wavelengths and fluxes. Much of the reduction work is done for the observer by the International Ultraviolet Explorer (IUE) Spectral Image Processing System (IUESIPS). Additional processing can improve the accuracy of the resulting wavelengths and fluxes. Because the processing of IUE data has not been uniform in its quality over the lifetime of IUE, the application of techniques used in the current IUESIPS can improve the quality of the data reduced in earlier epochs. This question was addressed in some depth by two earlier documents-CSC/TM-81/6117, Techniques of Reduction of IUE Data: Time History of IUESIPS Configurations (also NASA IUE Newsletter No. 16) and CSC/TM-81/6136, Techniques of Reduction of IUE Newsletter No. 17). Some of these techniques are presented again in this document because of their general utility. No effort has been made to address all of the processing defects as was done in the earlier documents. In addition, information is given in those areas where additional processing can improve the results beyond that provided by IUESIPS. The discussions will assume the reader is familiar with the output products provided by IUESIPS (see the International Ultraviolet Explorer Image Processing Information Manual, CSC/TM-81/6268).

This discussion of IUE data reduction is broken into four topics: documentation, wavelengths, fluxes, and signal-to-noise ratio. Each topic will be addressed separately, although, in fact, they are related. The documentation section discusses the types of information necessary to reduce IUE data and the best places to find this information. The wavelength section discusses those problems which affect the accuracy of the wavelength scale. The flux section concentrates on the accuracy and calibration of the flux distribution. Finally, the signal-to-noise ratio section discusses the steps which can be taken to optimize the information content of the data.

SECTION 2 - DOCUMENTATION

This section defines the location and encoding of the data necessary to reduce IUE spectra adequately. At the present time IUESIPS places most of this information within the scale factor record of the binary data (extracted spectral data). However, this information is also available in the science header and the processing history. Each of these areas will be discussed separately and the locations of useful information defined. Unfortunately, it is possible for the data in any or all the places to be incorrect or missing due to errors in the computer systems which generated the documentation. In this case, the user must resort to other documentation sources: the IUE Merged Observing Log, the Observing Scripts or the original observer's notes.

2.1 SCALE FACTOR RECORD

The scale factor record is the first record of the extracted spectral data. It contains the information used by IUESIPS to process the data. This information is gotten by examination of the science header records which document the acquisition of the data and from the processing done by IUESIPS. Due to changes in IUESIPS the completeness of this data is dependent on the processing date. For early images, the science header and the processing history are the only sources for some of this information. A list of the contents of the scale factor record as it is stored in the label file at the RDAFs is included in Appendix A. The format of this record on the Guest Observer tape is detailed in the International Ultraviolet Explorer Image Processing Manual, CSC/TM-81/6268 and is not repeated in this document.

2.2 SCIENCE HEADER INFORMATION

The science header is created by the operations software during the process of acquiring the original image. This header is composed of both EBCDIC and binary portions which are used to document the history of a specific image. The EBCDIC portions are created both by sampling the telemetry and by accepting data input from the telescope operator's console. The binary portions of the header are created from the telemetry and extracted from the Preplanned Observation Tape (POT). Thus in both cases the science header is partly machine-generated history and partly input information.

The science header is structured as a series of lines which are each 72 bytes long. When these lines are written to a tape, they are grouped into blocks of 5 lines which are therefore 360 bytes long. There are 100 lines defined in the science header created by the operations software. For purposes of reduction of IUE data only selected portions of the science header are useful. These portions are listed in Table 2-1. An example of the science header is included in Appendix B.

Table 2-1. Useful Science Header Records

Lines	Contents	Format	Source
1-2	System Label	EBCDIC	Operating System
3-9	Astronomer Comments	EBCDIC	Telescope Operator (TO)
10-32	Events Log	EBCDIC	Operations Procedures
36-37	Target Information	EBCDIC	Preplan Tape/TO
76-82	Spacecraft Snapshot	Binary	Telemetry
86-100	Camera Snapshots	Binary	Telemetry

Since the header is generated from different sources, information of interest to the data reduction appears in more than one place and format. The following sections describe the more important pieces of information within the science header.

2.2.1 DATES

The date of observation can be found in the Astronomer Comments. As this section of the science header is input by the telescope operator, there is no fixed location or format for this information. It has been standard practice at GSFC to include this information on line 6 of the science header. European observations normally include this information in the comments section but usually with the description of the observation rather than on a separate line.

The date and time of the read of an image are included in the events section by the operating system. As this information is entered automatically, its format and location are fixed. The date is stored in the first five characters of line 10 of the science header in the format YYDDD. YY is the last two digits of the year (e.g., 78 through 82) and DDD is the sequential day number within the year (i.e., January 1 = Day 001, and February 1 = Day 032). Note that this date is actually the date on which the image was read. The time associated with the read is given in characters 6 through 11 of the same line in the format HHMMSS, where HH is the hours, MM is the minutes and SS is the seconds since midnight GMT.

2.2.2 EXPOSURE LENGTH

The length of the exposure is recorded in several places within the science header. The telescope operator will normally record the length of the exposure in the Astronomer Comments section. As with the date, the format and location are not fixed. Goddard operations have usually recorded the total exposure time in the first line of comments (science header line 3).

In addition, the procedures which control the cameras accumulate the total time for which the camera high voltages were turned on. This value in seconds is recorded by the operating system in the second line of the science header, characters 30 through 35. Unfortunately, there are a number of common ways for this value to be incorrect. In particular, for trailed exposures or double aperture exposures the total camera on time is not related directly to the exposure time.

A third record of the exposure time is included in the events log. This record is entered by the software procedures which control the cameras. Whenever the camera is turned on for an exposure, the time, camera, and requested exposure time are recorded in the form:

```
HHMMSS EXPOBC n mm ss MAXG NOL *
```

where n is the camera number (1 = LWP, 2 = LWR, 3 = SWP, and 4 = SWR), HHMMSS is the time of the command in hours, minutes, and seconds, mm and ss are the requested exposure time in minutes and seconds, and MAXG and NOL are the camera operating modes (MAXG and NOL are the defaults for scientific images). The requested exposure time is stored in the event as integer values. This conversion to integer format results in a truncation error, which can yield a stored time, 1 second shorter than the requested. After an exposure is started, the exposure time is often modified. Modifications to the exposure time are recorded in the event log by the procedure which does the modification in the form:

```
HHMMSS MODTIME n mm ss            *
```

where the terms have the same meaning as for EXPOBC message. Modifying an exposure to a time shorter than the time already obtained automatically terminates the exposure, but the recorded time in the MODTIME event is the requested time. At the completion of each exposure, the telescope operator runs an accounting procedure which records the total accumulated exposure time and the nominal exposure termination time in the form:

```
    HHMMSS FIN n T sssss S 98 U 109 *
```

where sssss is the total camera exposure time in seconds. This time will not agree with the requested time recorded by EXPOBC if multiple exposures have been done or if the exposure time was modified after the exposure was begun.

As stated earlier, the requested camera exposure time is not related directly to the target exposure time when the target is trailed. Requests for trailing are recorded in the science header by the following events:

```
    HHMMSS TRAIL n  .rrrrrrE-rr     *
    HHMMSS TARGET IN aaaa           *
                     .
           (Camera events)
                     .
    HHMMSS TARGET FROM aaaa         *
    HHMMSS ITER m TIME  .ssssssE-ss *
```

where n is the camera number, .rrrrrrE-rr is the trail rate in arc-seconds per second, aaaa is the aperture name (LWLA, LWSA, SWLA, or SWSA), m is the number of passes completed and .ssssssE-ss is the total accumulated exposure time in seconds. The total accumulated exposure time is derived from the trail rate and the number of passes using a number of simplifying assumptions, including that the aperture length is precisely 20 arc-seconds. Because of these assumptions, the recorded exposure time is only approximately correct.

2.2.3 TARGET INFORMATION

The observer-supplied target information is normally recorded in lines 36 and 37 of the science header. The most important values are the right ascension and declination (normally epoch 1950) given in line 37 characters 1 through 14 in the format HHMMSSS±DDMMSS. HHMMSSS is the right ascension in HH hours, MM minutes, and SS tenths of seconds. The declination is given as ±DD sign and degrees, MM arcminutes, and SS arc-seconds. Unfortunately, normal operating procedures make it quite easy for these values to be wrong. A second source of the target information is the target identifier entered by the telescope operator in the Astronomer Comments and a suitable catalog.

2.2.4 CAMERA TEMPERATURES

IUESIPS extracts the camera head amplifier temperature (THDA) from the binary portions of the science header to correct the image geometry and dispersion relation. The values extracted are recorded in the processing history as well as elements 16 and 61 of the scale factor record.

Element		Contents
H(16)	=	(THDA in read) x 10
H(61)	=	(THDA in expose) x 10

Images processed before the introduction of this extraction (November 1981 for high and November 1980 for low dispersion) do not include this information in either the processing history or the scale factor record. However, the information is contained within the spacecraft snapshot and the camera snapshots. The following paragraphs will define how a user may extract this information.

In both cases (camera and spacecraft snapshot) the information is stored as raw telemetry. To use this data, the telemetry values must be converted to true temperatures.

This conversion is described in the IUE Command and Telemetry Users Manual (document number IUE-733-76-101) with a fifth order polynomial relating telemetered value to temperature:

$$\begin{aligned}\text{Temperature (degrees C)} = {} & 109.13 \\ & -131.91 \times (\text{telemetry value}/50.) \\ & + 84.903 \times (\text{telemetry value}/50.)^{2} \\ & - 30.540 \times (\text{telemetry value}/50.)^{3} \\ & + 5.3477 \times (\text{telemetry value}/50.)^{4} \\ & - 0.36411 \times (\text{telemetry value}/50.)^{5}\end{aligned}$$

At the RDAF this equation is implemented by a procedure called TCON.

The spacecraft snapshots are taken by the procedure which starts camera exposures. The following table lists the locations for the camera temperatures at the time of the snapshot. Each temperature is a single binary byte.

Camera	Line	Character
1 LWP	79	29
2 LWR	79	35
3 SWP	79	41
4 SWR	79	47

In addition to the temperatures, the time of the snapshot is stored as:

Quantity	Line	Character
Hours	76	1
Minutes	76	2
Seconds	77	65

Camera snapshots are taken by all the procedures which control the cameras. These dumps of camera telemetry are stored in a round-robin fashion using lines 86 through 100 of the science header. Each snapshot occupies one line of the header and contains a copy of the raw camera telemetry at the time of the snapshot. Table 2-2 lists the locations which contain the data pertinent to the camera temperatures.

Table 2-2. Camera Snapshot Locations Containing Camera Temperature Information

Character	Contents
1	Time-hours
2	Time-minutes
58	Time-seconds
41	Temperature
56	Camera Number
57	Procedure Number

Early versions of the IUE operating system failed to store the data in these areas correctly. If the snapshot contains an illegal camera or procedure number the remaining information cannot be trusted and the data from the spacecraft snapshot should be used. The current definitions of valid camera and procedure numbers are listed in Table 2-3.

Table 2-3. Valid Camera and Procedure Numbers

Number	Camera	Procedure
0	-	Unknown
1	LWP	Prepare exposure
2	LWR	Fast erase
3	SWP	Read-rate erase
4	SWR	Exposure beginning
5	-	Exposure middle
6	-	Exposure end
7	-	Read scan
8	FES1	Read stationary
9	FES2	Standby
10	-	Emergency
11	-	Camera off
12	-	Read-rate bad scan
13	-	Read bad scan

2.3 PROCESSING HISTORY

A second source of information about an image is the EBCDIC processing history which IUESIPS appends to the science header. This information describes the processing done by IUESIPS and the parameter values it derived from the operations science header. The processing history is structured in a manner similar to the science header. Examples of the processing history are included in Appendix C. The following sections describe some of the quantities that may be found in this history.

2.3.1 DATES

The processing date is useful in the investigation of processing defects as defined by the IUESIPS time history documentation (CSC/TM-81/6117, Techniques of Reduction of IUE Data: Time History of IUESIPS Configurations) which appeared in NASA IUE Newsletter No. 16. This date is included in the processing history after the log of each applications program. These lines can be recognized by the format

```
    *xxxxxx  09:34Z JUL 16,'81                          HC
```

where xxxxxx is the name of the applications program.

2.3.2 DISPERSION CONSTANTS

IUESIPS records the dispersion constants in the format:

```
B 1= s.nnnnnnnnnnnnD ee B 2= s.nnnnnnnnnnnnD ee B 3= s.nnnnnnnnnnnnD eeC
A 1= s.nnnnnnnnnnnnD ee A 2= s.nnnnnnnnnnnnD ee A 3= s.nnnnnnnnnnnnD eec
```

For low dispersion, the B 3 and A 3 values will always be zero. For high dispersion, subsequent lines will contain the higher order constants. The dispersion constants written here have been modified from the nominal values to account for the thermal and registration shifts which follow the dispersion constants in the processing history. These shifts affect the B 1 and A 1 terms.

2.3.3 EXTRACTION PARAMETERS

The nominal aperture from which the data are extracted is recorded in the format

```
    ********  DATA FROM LARGE APERTURE ********        C
```

For low dispersion spectra, additional information about the extraction is listed in the lines just prior to the dispersion constants. Normally the length of the extraction slit (HT), the angle of the extraction slit makes with the dispersion line (OMEGA), the location of the background (DISTANCE), and the length of the background extraction (HBACK) are included.

2.3.4 RADIAL VELOCITY CORRECTIONS

High dispersion processing since November 1981 has included the radial velocity corrections for the Earth and spacecraft motions. To compute these corrections the program needs to know the date and time of the observation, and the pointing of the spacecraft. The values used are recorded in the processing history, along with the derived rectangular velocities of the spacecraft and Earth, and the net radial velocity correction which was applied. These quantities will be correct if the information the processing system derived from the science header was correct.

SECTION 3 - WAVELENGTHS

This section will cover the corrections necessary to improve on the wavelength scale generated by IUESIPS. There are three areas in which improvements can be made: the dispersion constants, the radial velocity of the spacecraft, and random errors. Each of these areas will be addressed separately in terms of the processing necessary to improve or correct the problem.

3.1 DISPERSION CONSTANTS

The dispersion constants used to process the image are recorded in the processing history and more recently in the scale factor record (see Section 2 for details). The dispersion constants are the coefficients for two polynomials which describe the location of the data in the image format of the camera (i.e., line and sample number as a function of wavelength).

Except for a few images processed very early in IUE's lifetime, IUESIPS has modified the nominal dispersion relation to register the extraction slit with the spectrum and recorded these modified constants in the processing history. As a hedge against secular changes in the dispersion relation, IUESIPS used constants derived from biweekly measurements of the wavelength calibration lamp. Unfortunately, the stability of the dispersion constants has been inadequate due to inaccuracies in their derivation. Several improvements can be made to the wavelength scale by simply correcting the old dispersion relation to the time and temperature corrected means which are used in the present IUESIPS processing. A variation on this correction technique can be used to correct for other errors introduced by time and temperature effects or operator shifts.

For low dispersion spectra, the data are extracted from the image using a linear dispersion relationship for both line and sample as a function of wavelength:

$$\text{Sample} = A1 + A2 \times \text{Lambda}$$

$$\text{Line} = B1 + B2 \times \text{Lamdba}$$

Changing the dispersion relation nominally means that the data must be reextracted from the image. However, one can perform a simpler transformation which uses the new constants to derive an effective wavelength for the old extraction. Harvel et al. (NASA IUE Newsletter No. 5) presented a detailed discussion of this technique. This correction implicitly assumes that the extraction slit used actually included the real data and that computing the intersection of the extraction slit and the new dispersion relation will determine a corrected wavelength. If one assumes that the extraction slit is normal to the dispersion relation then the correction becomes:

$$\text{Lambda}' = \frac{A2 \times (A1 - A1') + B2 \times (B1 - B1') + (A2 \times A2 + B2 \times B2) \times \text{Lambda}}{A2 \times A2' + B2 \times B2'}$$

where the primes refer to the corrected relations.

For the high dispersion spectra, the data are extracted from the image with a more complex set of equations involving both the wavelength, L, and the order number, M:

$$\begin{aligned}\text{Sample} = {} & A1 + A2 \times M \times L + A3 \times M \times M \times L \times L + A4 \times M \\ & + A5 \times L + A6 \times M \times M \times L + A7 \times M \times L \times L\end{aligned}$$

$$Line = B1 + B2xMxL + B3xMxMxLxL + B4xM + B5xL + B6xMxMxL + B7xMxLxL$$

Unfortunately, it is not possible to solve these equations as was done for the low dispersion set to give a single relation between original and corrected wavelengths. Nonetheless, it is possible to set up an approximation by linearizing the equations and using the correction relation defined for the low dispersion.

The sample equation can be linearized by replacing L with Lo + D, which gives

$$\begin{aligned} Sample = {} & (A1 + A4xM) \\ & + (A2 x M + A3xMxMxLo + A5 + A6xMxM + A7xMxLo) x Lo \\ & + (A2xM + 2xA3xMxMxLo + A5 + A6xMxM \\ & + 2xA7xMx Lo) x D + (A3xMxM + A7xM) x D x D \end{aligned}$$

and noting that when D is small compared to Lo the last term can be ignored. Thus the linearized equations are of the form:

$$Sample = A^*1 + A^*2 x D$$

$$Line = B^*1 + B^*2 x D$$

where the constants are given by:

$$\begin{aligned} A^*1 = {} & A1 + A4xM + (A2xM + A3xMxM x Lo + A5 \\ & + A6xMxM + A7xMxLo) x Lo \end{aligned}$$

$$A*2 = A2xM + 2xA3xMxMxLo + A5 + A6xMxM + 2xA7xMxLo$$

$$\begin{aligned} B*1 = {} & B1 + B4xM + (B2xM + B3xMxMxLo + B5 \\ & B6xMxM + B7xMxLo) \ x \ Lo \end{aligned}$$

$$\begin{aligned} B*2 = {} & B2xM + 2xB3xMxMxLo + B5+B6xMxM \\ & 2xB7xMxLo \end{aligned}$$

As D represents a delta wavelength from Lo, when these constants are substituted into the low dispersion correction formula, D may be set to zero and the correction applied for each value of Lo. In this case, D'(Lo) becomes the correction to the original wavelength Lo.

$$D' = \frac{A*2 \ x \ (A*1') + B*2 \ x \ (B*1 - B*1')}{A*2 \ x \ A*2' + B*2 \ x \ B*2'}$$

and the corrected wavelength Lo' = Lo + D'.

To estimate the errors caused by the linearization process, the value of the ignored term

$$(A3xMxM + A7xM) \ x \ D \ x \ D$$

must be examined. First we recast the expression into slightly different form:

$$(A3xMxLoxMxLo + A7xMxLoxLo) \ x \ \frac{D}{Lo} \ x \ \frac{D}{Lo}$$

If Lo is taken to be the order center, then M x Lo is the grating constant K. Further, by examining A3 and A7 in the default dispersion relations, the second term can be shown to be at least two orders of magnitude smaller than the first. Thus the error at the order center can be written as

$$A3 \times K \times K \times \frac{D}{Lo} \times \frac{D}{Lo}$$

at the center of each order. Inserting the default dispersion relations (both line and sample directions), we find that a 200 km/sec correction computed with the linearized equations gives an error no greater than 1 km/sec.

3.1.1 MEAN CONSTANTS

IUESIPS (NASA IUE Newsletter No. 15) has published the mean dispersion relations for both the LWR and SWP cameras. To correct any set of data to these means merely requires substituting the values from Table 3-1 into the appropriate equation (either high or low dispersion) as the corrected constants and the constants in the science header as the actual constants.

3.1.2 TIME AND TEMPERATURE EFFECTS

The mean dispersion constants are based on a mean camera temperature and the mean time over which they were determined. Thompson (1981, IUE Newsletter No. 15) has shown that there are shifts in the spectral format which are correlated with both time and temperature. Data that are corrected for these shifts using a linear approximation for the changes in A1 and B1 with time and temperature, give better wavelength scales than those determined with either the biweekly dispersion constants in use during the first 2 years of IUE or the mean dispersion constants. The following constants define the time and temperature dependence (Table 3-2).

Table 3-1. Mean Dispersion Constants

	LWR High	LWR Low	SWP High	SWP Low
		For Small Aperture Exposures		
A1	-5094.526	-298.613	981.209	982.251
B1	15466.845	-265.508	-6566.373	-263.500
		For Large Aperture Exposures		
A1	-5113.126	-317.213	963.809	964.851
B1	15486.245	-246.108	-6586.073	-283.200
		For All Exposures		
A2	14925.106E-5	302.371E-3	-17760.506E-5	-466.519E-3
B2	-27798.582E-5	225.700E-3	-12709.243E-5	376.206E-3
A3	-5566.622E-10		12924.643E-10	
B3	9089.256E-10		12553.362E-10	
A4	0.218E-2		3.131E-2	
B4	8.456E-2		0.0	
A5	275.161E-3		-465.499E-3	
B5	223.411E-3		407.922E-3	
A6	0.0		-2.268E-7	
B6	-0.766E-7		0.172E-7	
A7	11.722E-8		-1.440E-8	
B7	1.770E-8		-23.770E-8	

Table 3-2. Time and Temperature Dependence

Coefficient	LWR High	LWR Low	SWP High	SWP Low
WA1	4.855	4.483	-1.704	-2.033
WB1	-8.347	-8.235	-2.357	-1.536
WA2	-0.2797	-0.2165	0.0352	0.0206
WB2	0.5522	0.5035	0.2262	0.1761
WA3	-1.556E-3	-2.172E-3	1.841E-3	2.435E-3
WB3	1.482E-3	2.204E-3	0.658E-3	0.138E-3

where

$$A1' = A1 + WA1 + WA2 \times THDA + WA3 \times Time$$

$$B1' = B1 + WB1 + WB2 \times THDA + WB3 \times Time$$

THDA is the temperature during the read and Time is in days since January 1, 1978.

As these shifts are applied only to the A1 and B1 terms of the dispersion relation, a simplified correction of the same form as the original can be used. The change in wavelength (Delta) can be computed using the following formula:

$$Delta = \frac{A2 \times (A1' - A1) + B2 \times (B1' - B1)}{A2 \times A2 + B2 \times B2}$$

for low dispersion and the corresponding linearized equation for high dispersion (i.e., replace A2 and B2 by A*2 and B*2).

3.1.3 OPERATOR SHIFTS

Another correction that can be made using this basic correction technique is for the shifts made by the image processing operator. These shifts are used to register the extraction slit with the data. Currently, for most images this registration is done automatically by moving the extraction slit normal to the dispersion relation which should leave the wavelength scale unaffected. At times, this shift is done manually by the operator and, in the past, were made in an arbitrary direction. Because the shifts are recorded in the image processing label and are applied only to the A1 and B1 terms of the dispersion relation, a simplified correction of the same form as the original can be used. The change in wavelength (Delta) can be computed using the following formula:

$$\text{Delta} = \frac{\text{A2 x (Sample shift) + B2 x (Line shift)}}{\text{A2 x A2 + B2 x B2}}$$

for low dispersion and the corresponding linearized equation for high dispersion (i.e., replace A2 and B2 by A*2 and B*2).

3.2 RADIAL VELOCITY CORRECTIONS

Currently IUESIPS corrects the high dispersion wavelength scales for the radial velocity of the Earth and spacecraft motions. This correction is recorded in the processing history as the target attitude, the date and time of the observation, and the resultant X, Y, and Z velocity components of the Earth's motion around the Sun and of the spacecraft's motion around the Earth. Then IUESIPS computes a net radial velocity correction which is applied to the data and also recorded in the processing history.

The net radial velocity correction for a star located at right ascension, a, and declination, d, can be computed from the net spacecraft velocity in rectangular coordinates Vx, Vy, and Vz by a simple coordinate transformation:

$$\text{Velocity} = Vx \times \cos(d) \times \cos(a) + Vy \times \cos(d) \times \sin(a) + Vz \times \sin(d)$$

$$\text{Corrected Wavelength} = \text{Wavelength} \times (1 + \text{Velocity}/299792.5 \text{ km/sec})$$

Equations to derive the X, Y, and Z velocity components are described in the following sections.

3.2.1 EARTH ORBIT

The Earth's velocity around the Sun is of the order 30 km/sec. This velocity can create wavelength shifts in the spectrum comparable to the IUE resolution. Currently IUESIPS corrects all high dispersion spectra for the Earth motion using the algorithm described by Harvel (1980, NASA IUE Newsletter No. 10). Although this algorithm can be used to calculate the Earth's motion, it is far more complex than is really needed.

Some judicious checking has shown that it is possible to simplify the calculations by using the approximation for the Sun's position described in The Astronomical Almanac (1982, U.S. Government Printing Office, p. C20) and achieve an accuracy of approximately three parts in a thousand or 0.1 km/sec:

$$L = 279.336 + 0.98565 \times \text{Day (degrees)}$$

$$G = 356.711 + 0.98560 \times \text{Day (degrees)}$$

$$\text{LAMBDA} = L + 1.916 \times \sin(G) + 0.020 \times \sin(2 \times G) \text{ (degrees)}$$

where DAY is the interval in days since January 0, 1982, at 0 hours UT, L is the mean longitude of the Sun, G is the mean anomaly and LAMBDA is the ecliptic longitude. These quantities can be used to compute the location and velocity of the Earth in rectangular coordinates with:

$$R = 1.0 - 0.0167 \times \cos(G) \ \text{(au)}$$

$$X = -R \times \cos(\text{LAMBDA}) \ \text{(au)}$$

$$Y = -0.9175 \times R \times \sin(\text{LAMBDA}) \ \text{(au)}$$

$$Z = 0.4336 \times Y \ \text{(au)}$$

and

$$\text{Vlambda} = 29.786 + 0.996 \times (\cos(G) + 0.0209 \times \cos(2 \times G)) \ \text{(km/au/sec)}$$

$$\text{Vr} = 0.497 \times \cos(G) \ \text{(km/sec)}$$

$$\text{Vx} = R \times \sin(\text{LAMBDA}) \times \text{Vlambda} - \text{Vr} \times \cos(\text{LAMBDA}) \ \text{(km/sec)}$$

$$\text{Vy} = 0.9175 \times (X \times \text{Vlambda} - \text{Vr} \times \sin(\text{LAMBDA})) \ \text{(km/sec)}$$

$$\text{Vz} = 0.4336 \times \text{Vy} \ \text{(km/sec)}$$

This approximation has been checked against tables given in The Astronomical Almanac, from 1978 through 1982, and no errors greater than 0.1 km/sec were found. If the relation is extrapolated until 1986 the errors are expected to be of comparable magnitude.

3.2.2 SPACECRAFT ORBIT

Unfortunately, no simple approximation for the orbit of the IUE exists. However, Harvel (1980, NASA IUE Newsletter No. 10) has published a general solution for the rectangular velocities Vx, Vy, and Vz from the orbital elements.

Vx = Vo x (V2 x (C4xC3xC7 - C5xC8)

- V1 x C1 x (C5xC7 + C4xC3xC8))/V3

Vy = Vo x (V1 x C1 x (C4xC5xC8 - C3xC7)

- V2 x (C4xC5xC7 + C3xC8))/V3

Vz = Vo x C2 (V1xC1xC8 - V2xC7)/V3

where the following intermediate values have been used

Vo = mean velocity = 6.283185 x semimajor axis/period
C1 = SQRT(1 - eccentricity x eccentricity)
C2 = sin(inclination)
C3 = sin(longitude of the ascending node)
C4 = cos(inclination)
C5 = cos(longitude of the ascending node)
C7 = sin(argument of perigee)
C8 = cos(argument of perigee)
V1 = cos(eccentric anomaly)
V2 = sin(eccentric anomaly)
V3 = 1 - eccentricity x cos(eccentric anomaly)

All the constants needed to calculate the intermediate values listed above are included in the basic orbital elements except for the eccentric anomaly. To calculate the eccentric anomaly, one must calculate the mean anomaly for the time in question and then solve Kepler's equation

$$MA = (Mo + 360 \times (T - To)/P) \text{ modulo } 360 \text{ (degrees)}$$

and

$$MA = EA - \text{eccentricity} \times \sin(EA) \text{ (radians)}$$

where MA is the mean anomaly at time T, Mo is the mean anomaly at time To, P is the orbital period in the same units as T and To, and EA is the eccentric anomaly.

Kepler's equation cannot be solved directly but fortunately there exists a straightforward iterative solution technique:

$$EA' = EA + \frac{MA - EA + \text{eccentricity} \times \sin(EA)}{1 - \text{eccentricity} \times \cos(EA)}$$

where EA' is the refined eccentric anomaly (Smart, Text-Book on Spherical Astronomy, p. 114). To start this solution, an initial guess for the eccentric anomaly is required. For IUE's orbital eccentricity (approximately 0.23) using the mean anomaly (i.e., EA = MA) is sufficiently accurate for convergence to six decimal places after six iterations.

IUESIPS uses a set of mean orbital elements from 1979 day 326 to compute spacecraft motions. Rather than use the actual orbital period from that epoch the processing system uses exactly one siderial day for IUE's period. This approximation is a simple means of accounting for the orbital period corrections which are done every 10 to 12 months to keep the IUE's ground track over the Atlantic Ocean. These nominal orbital elements are listed in Table 3-3.

Table 3-3. Nominal IUE Orbital Elements

Epoch	1979 day 326 00:00 UT
Period	86,164.04 seconds
Mean anomaly	246.56000 degrees
Semimajor axis	42,163.2 km
Eccentricity	0.2359693
Inclination	28.272837 degrees
Longitude of the ascending node	193.96197 degrees
Argument of perigee	270.91300 degrees

Substituting these values into the equations given by Harvel yields the following simplified equations for the spacecraft motion

V1 = cos(eccentric anomaly)
V2 = sin(eccentric anomaly)
V3 = 1 - 0.2360 x cos(eccentric anomaly)
Vx = (-2.889 x V1 + 0.701 x V2)/V3 (km/sec)
Vy = (-0.762 x V1 - 2.616 x V2)/V3 (km/sec)
Vz = ($\overrightarrow{0}$.023 x V1 + 1.456 x V2)/V3 (km/sec)

These equations appear to be good to approximately 1.5 km/sec from launch to the present time. Unfortunately, the errors are caused by an evolution of the orbital elements with time due to the nonsphericity of the Earth. For this reason the expected errors if these relations were extrapolated into the future cannot be adequately estimated but should be no smaller than the present errors (1.5 km/sec).

A somewhat better extrapolation can be achieved by using mean orbital elements from an epoch closer to the present. A check of the orbital predictions supplied to the IUE project yields the following elements listed in Table 3-4.

Table 3-4. Current Epoch IUE Orbital Elements

Epoch	1982 day 0 00:00 UT
Period	86,164.04 seconds
Mean anomaly	289.68000 degrees
Semimajor axis	42,157.6 km
Eccentricity	0.2266634
Inclination	28.383000 degrees
Longitude of the ascending node	177.35300 degrees
Argument of perigee	-72.68200 degrees

The elements yield the following equations for the spacecraft motion:

V1 = cos(eccentric anomaly)
V2 = sin(eccentric anomaly)
V3 = 1 - 0.2267 x cos (eccentric anomaly)
Vx = (-2.892 x V1 + 0.795 x V2)/V3 (km/sec)
Vy = (-0.651 x V1 - 2.622 x V2)/V3 (km/sec)
Vz = ($\overrightarrow{0}$.424 x V1 + 1.395 x V2)/V3 (km/sec)

These equations should give no worse than 1.5 km/sec errors for the next 2-1/2 years if the orbital corrections in that period are the same magnitude as in the past 3 years.

The extrapolation can be eliminated for any time through 1980 by using the actual orbital elements published by Ehlers (1981, NASA IUE Newsletter No. 14). These elements are tabulated on 7 day intervals and so can be used directly without any interpolation. If interpolated orbital elements are desired, care must be taken not to interpolate across orbital correction maneuvers because the derivatives of the elements are discontinuous at the times of these correction maneuvers.

3.3 REGISTRATION OF SPECTRA

Having corrected the spectra for the above problems, there will be a dispersion in the velocities of various features on a number of spectra. It is possible to improve the wavelength scale for these random errors by registering spectra of the space object in the same manner as the fluxes are improved by averaging spectra. The resulting mean wavelength scale is presumably the best, based on the unproven assumption that the wavelength errors are random. In order to register the spectra, one must locate features in each spectrum whose wavelengths are fixed. There are two possible methods for locating this invariant wavelength frame: interstellar lines and fine structure within the spectrum.

Interstellar lines would appear to be the best invariant frame for registering IUE data since all the effects resulting in shifts of the wavelength scale are corrected. In practice there are several difficulties. The foremost difficulty is the small number of lines available. Each measurement of a line position has an intrinsic error which is approximately 10 percent of the instrumental resolution or 3 km/sec for IUE. To improve the accuracy requires the averaging of a number (preferably more than 10) measurements. Typical objects with interstellar lines contain no more than 6 to 12 suitable lines. In addition, there is a significant number of objects with no interstellar lines. A secondary problem is the identification of appropriate lines. Many of the interstellar lines can be formed in the stellar spectrum and in circumstellar material as well. In both of these cases, one can question how fixed the wavelength frame is.

To overcome the problems of too little information being provided by the interstellar lines, whole chunks of the sprectrum can be compared using cross correlation techniques to determine relative shifts. This technique has the advantage of massing large amounts of data into the measurement which should result in significant improvements in the accuracy of the measured shift. Unfortunately, this increase in accuracy is strongly dependent on the assumption that the noise is described by Poisson statistics and that the features in the spectra really arise from a fixed wavelength frame. Both of these assumptions can be questioned. Sensitivity monitoring done in low dispersion indicates that the best reproducability even in wide bandpasses (20 to 60 resolution elements) is 3.5 percent rather than the 1.5 percent expected if Poisson statistics applied. Concerning the invariability of the wavelength frame of the features, the existence of camera related features as seen by Davidson et al. (1982, Ap. J, 253, 696) in low dispersion indicates there are at least two independent invariant wavelength frames for features: the object and the camera.

SECTION 4 - FLUXES

This section discusses the best determination of flux using IUE data. IUESIPS does the majority of the conversion from data numbers (DNs) to the units of energy. However, there are a number of techniques a user can apply to improve upon or extend the IUESIPS results. The following sections will address five such techniques: determination of the correct exposure time, improvements for the sensitivity function, correction for nonlinearities in the image transfer function, correction for the echelle blaze function, and the effects of backgrounds on the data.

4.1 EXPOSURE TIMES

The IUESIPS processing does not account for the exposure time of an image. The results supplied to the IUE observer are the total energy observed. As most observers desire energy per unit time, it is necessary to divide the energy by the total exposure time. This exposure time is recorded by IUE science operations in a number of places within the science header as described in Section 2. There are two basic techniques by taking exposures with the IUE satellite: point source and trailed exposures. Each of these techniques uses different hardware to control the exposure and so the corrections from the requested to the actual exposure time are different.

4.1.1 POINT SOURCE EXPOSURES

Point source exposures are taken by turning on the high voltages in the image intensifier portions of the cameras. The high voltages are turned off when the requested time has been reached. This method of controlling the exposure time introduces a number of errors for which corrections are possible and creates a fundamental uncertainty in the length of the exposure.

The timing of the exposures is done by the On-Board Computer (OBC). The ground system sends to the OBC a sequence of commands designed to turn the voltages on, wait for the desired time, and then turn the voltages off. The timing of the wait is done by counting pulses from an internal digital clock within the OBC which occur every 0.4096 seconds. The conversion from the requested time in seconds to OBC clock pulses is done by the ground computer. This conversion results in a truncation of the effective exposure time to the nearest multiple of 0.4096 seconds smaller than the requested time. In order to correct the requested exposure time, you must divide by 0.4096 seconds, take the integer portion and multiple by 0.4096 seconds. For multiple exposures, this error occurs for each exposure, hence a triple exposure might have an error of as much as 1.2 seconds.

A second error in the exposure time comes from the "shuttering" technique. The high voltage power supply which is switched does not turn on or off in zero time. In fact, the exposure is measurably shorter than the requested time due to this effect. Measurements indicate that this error shortens the exposure time by approximately 120 milliseconds. There is no reason this error should be the same in each camera but the measurements for the LWR and SWP are consistent with a single value. The value for the LWP is unknown.

While measuring the camera voltage risetime, the IUE staff measured a fundamental uncertainty in the exposure time of 15 milliseconds. This uncertainty occurs in the process by which the OBC issues commands. Due to the timing of the code in the OBC, there is a 30 millisecond window for each command. Unfortunately, unlike the previous errors, this uncertainty cannot be corrected because of its stochastic nature.

4.1.2 TRAILED EXPOSURES

The second technique for timing exposures is to use the spacecraft maneuvering system to "shutter" the exposure by slewing the target at a uniform rate across the entrance aperture. As IUE's large entrance aperture is larger than the telescope image for a point source, the exposure is smeared on the target and so this mode of observing is referred to as trailing. As the actual exposure time is determined by the maneuvering subsystem and the recorded times by the camera commands, the exposure times recorded automatically in the science header are incorrect (see Section 2 for more details). The correct exposure time can be computed by dividing the length of the aperture by the rate requested and multiplied by the number of passes made. The current best estimates for the length of a trail through the large aperture are given below (see Panek, 1982, NASA Newsletter No. 18 for details):

Table 4-1. Trail Lengths

Spectrograph	Aperture Length	Width
Long	20.5±1.0	9.2±0.1
Short	21.4±0.4	8.8±0.3

Nonlinearities in the trail rates have been seen for the fastest trails (approximnately 60 arc-seconds per second), but corrections have not been derived.

4.2 SENSITIVITY

IUE has been blessed with a stable set of detectors. For this reason, there has been very little concern with corrections to the instrumental sensitivity since the publishing of the absolute calibrations (Bohlin and Holm, 1980, NASA IUE Newsletter No. 10, and Cassatella et al., 1981, NASA IUE Newsletter No. 14). For completeness these calibrations are included in Appendix D.

Nonetheless, the IUE Observatory has undertaken to monitor the instrument performance by repeated observations of a subset of standard stars. At the present time, there is significant information about the low dispersion sensitivity variations with both time and temperature. (Holm and Schiffer, 1980, NASA IUE Newsletter No. 9, Schiffer, 1982, NASA IUE Newsletter No. 18, and Schiffer, 1982, NASA IUE Newsletter No. 19.) Unfortunately, the monitoring program for high dispersion spectra is significantly more difficult to interpret and so essentially no results are available. There are indications that there have been recent changes in the LWR camera sensitivity in the high dispersion mode (Ake, 1981, NASA IUE Newsletter No. 19). These changes appear as a change in the effective echelle blaze function.

The following sections summarize the low dispersion results. These results are derived from approximately 100 observations of four standard stars: BD+28 4211, HD 93521, HD 60753, and BD+33 2642 in both the LWR and SWP cameras. These data were ratioed to a reference spectrum, smoothed and binned. The smoothing was done with a median filter to eliminate the effects of wavelength misregistration and reseau marks. The resulting data set was fit using multiple linear regressions to a single temperature coefficient for each camera, and a single time dependence for each wavelength.

4.2.1 TEMPERATURE CORRECTIONS

The derived temperature corrections are related to the camera head amplifier temperature (THDA) during the exposure:

Table 4-2. Sensitivity Change With Temperature

Camera	Percent/Degree Change
LWR	-1.1 percent
SWP	-0.5 percent

The values for the non-operational cameras are unkown. These numbers have an 0.5 percent/degree uncertainty, although the observed scatter is significantly smaller. Prelaunch measurements indicate the photocathode and UV converter phospher should have approximately -0.8 percent/ degree change in sensitivity with temperature. These prelaunch measurements are consistent with the monitoring measurements.

When the data are corrected for this effect, the RMS errors seen are approximately 3 percent for the 150-Angstrom bins in the SWP camera and 3.5 percent for the 100- to 300-Angstrom bins in the LWR camera (times of rapid temporal changes being excluded from the determination).

4.2.2 TIME VARIATIONS

In addition to the temperature variations, the data for both the LWR and SWP cameras show evidence for temporal changes in the sensitivity. Unfortunately, the monitoring analysis does not give any details as only three wavelength bins are considered in each camera. It is not obvious that the variations measured can be either interpolated or extrapolated to other wavelengths, because more detailed analysis of the LWR high dispersion spectra has shown that the entire image is changing in some complicated manner.

Table 4-3. Sensitivity Variations With Time
(Percent/Year)

Camera	Wave length	Width	Before 1979.3	1979.3-1980.5	After 1980.5
SWP	1300 A	150 A	-	-	-
	1550 A	150 A	-6.3	-	-
	1850 A	150 A	-6.1	-	-
LWR	2400 A	300 A	-	-	-3.3
	2600 A	100 A	-	-	-1.0
	2900 A	300 A	-	-	-1.8

(- indicates no measurable change.)

4.3 ITF NONLINEARITIES

The Intensity Transfer Function (ITF) is defined by a table which linearizes the detected signal, i.e. transforms observed data numbers into flux numbers (FNs). In 1979 an error was found in the construction of the ITF for the SWP camera. This error adversely affected the photometric quality of the data processed before mid-1979. Further analysis of both the corrected SWP ITF and the LWR ITF have shown that errors exist in both ITFs (Holm, 1980, 1981 and 1982, reports to the Three-Agency meetings).

In principle, errors in the ITF require reprocessing of the image. In practice, small errors in the ITF can be corrected with reasonable accuracy by modifying the contents of the line-by-line (ESSR) file using an equation of the form:

$$FN' = A(FN,Lambda) \times FN + B(FN,Lambda)$$

where FN is the flux number value of a single pixel in the original image. Presently only the parameters for the original SWP ITF error have been published (Cassatella et al., 1980, NASA IUE Newsletter No. 8 and are reproduced here in Table 4-4.

Table 4-4. Corrections for SWP ITF Error (1 of 2)

Flux numbers < 1084: A = 0.960 B = 0 (for either aperture)
Flux numbers > 4291: A = 1.000 B = 0 (for either aperture)

Coefficients for Large Aperture Fluxes

Flux Range	1084 to 2141		2141 to 2684		2684 to 4291	
Wavelength	A	B	A	B	A	B
1100	0.2561	763	1.3674	-1616	1.3670	-1615
1150	0.2517	768	1.3830	-1654	1.3644	-1604
1200	0.2725	746	1.3560	-1574	1.3602	-1585
1250	0.2791	738	1.3907	-1642	1.3441	-1516
1300	0.2952	721	1.3771	-1595	1.3383	-1492
1350	0.3103	704	1.3421	-1504	1.3399	-1499
1400	0.3226	691	1.3252	-1455	1.3375	-1488
1450	0.3415	671	1.2900	-1360	1.3366	-1484
1500	0.3415	671	1.3073	-1397	1.3309	-1460
1550	0.3623	648	1.2581	-1270	1.3333	-1470
1600	0.3557	655	1.2860	-1336	1.3284	-1449
1650	0.3576	653	1.2580	-1274	1.3366	-1484
1700	0.3482	664	1.2602	-1289	1.3424	-1509
1750	0.3415	671	1.2662	-1309	1.3449	-1520
1800	0.3321	681	1.2729	-1333	1.3491	-1538
1850	0.3160	698	1.2669	-1337	1.3627	-1596
1900	0.2573	762	1.3603	-1599	1.3688	-1622
1950	0.2271	795	1.3945	-1704	1.3766	-1656
2000	0.1968	828	1.4132	-1776	1.3899	-1713

Table 4-4. Corrections for SWP ITF Error (2 of 2)

Coefficients for Small Aperture Fluxes

Flux Range	1084 to 2141		2141 to 2684		2684 to 4291	
Wavelength	A	B	A	B	A	B
1100	0.2271	795	1.4315	-1784	1.3636	-1600
1150	0.2431	777	1.4191	-1740	1.3576	-1574
1200	0.2621	757	1.3906	-1659	1.3550	-1563
1250	0.2668	752	1.4018	-1678	1.3483	-1534
1300	0.2971	719	1.3407	-1515	1.3491	-1538
1350	0.3065	709	1.3175	-1456	1.3508	-1545
1400	0.3150	699	1.3228	-1458	1.3433	-1513
1450	0.3169	697	1.3094	-1427	1.3455	-1527
1500	0.3340	679	1.2739	-1333	1.3474	-1531
1550	0.3444	668	1.2820	-1340	1.3375	-1488
1600	0.3529	658	1.2603	-1284	1.3391	-1495
1650	0.3576	653	1.2486	-1254	1.3399	-1499
1700	0.3557	655	1.2407	-1239	1.3441	-1561
1750	0.3368	676	1.2661	-1314	1.3482	-1534
1800	0.3245	689	1.2690	-1333	1.3559	-1567
1850	0.3236	690	1.2616	-1318	1.3593	-1582
1900	0.2933	723	1.3134	-1463	1.3610	-1589
1950	0.2687	750	1.3368	-1537	1.3696	-1626
2000	0.2365	785	1.3311	-1559	1.3943	-1732

A number of methods were devised to cope with this SWP ITF error and were reported by Holm and Schiffer (1980, NASA IUE Newsletter No. 8). The next two sections present two possible correction techniques: the Three-Agency approved correction and a quadratic interpolation correction. These correction techniques differ in the approximation used to deduce the FN value of the original pixel in the image from the flux number value recorded in the line-by-line file.

4.3.1 THREE-AGENCY METHOD

After significant discussion, the Three-Agency Committee elected to endorse the simplest form of correction algorithm in which the value of a sample from the line-by-line is assumed to be equal to twice that of a pixel in the original image. This correction correctly accounts for area of the sampling slit (samples in the line-by-line file have an area of two pixels on the original image) but is an approximation as the slit is actually a weighted average of 4 to 7 camera pixels.

4.3.2 QUADFIX METHOD

In an effort to overcome the compromises in the Three-Agency correction method, Holm and Schiffer devised a quadratic interpolation correction for the line-by-line (ESSR) files. The Quadfix method assumes that each line in the line-by-line is actually an average of three diagonals in the image with a 1/2-1-1/2 weighting. Further, the method assumes that the pixel values vary only in the direction normal to the dispersion and that a quadratic interpolation between the ESSR lines will give the values for the intermediate pixels.

These assumptions give the following decomposition of the value, S(J,K), found in the Jth line, Kth sample of the line-by-line file into single-pixel flux numbers, FN:

$$FN(J-1/2) = \frac{7}{16} \times S(J,K) + \frac{5 \times S(J-1,K) - 3 \times S(J+1,K)}{32}$$

$$FN(J) = \frac{9}{16} \times S(J,K) - \frac{S(J-1,K) + S(J+1,K)}{32}$$

$$FN(J+1/2) = \frac{7}{16} \times S(J,K) + \frac{5 \times S(J+1,K) - 3 \times S(J-1,K)}{32}$$

These FNs can then be corrected using the basic correction equation listed in Section 4.3. The corrected sample value, S'(J,K), is obtained from:

$$S'(J,K) = FN'(J) + \frac{FN'(J-1/2) + FN')J+1/2)}{2}$$

4.4 RIPPLE CORRECTION

Ake (1981, NASA IUE Newsletter No. 15) has shown that the functional form used by IUESIPS for the blaze correction of the echelle grating was incorrect. Fortunately, the differences between the correct function and the function used by IUESIPS are small. The correct function has a different formulation, a dependence on order number (shown earlier by Ahmad, 1981, NASA IUE Newsletter No. 14) and a possible time dependence with the LWR camera. Each of these points is addressed in a following section.

4.4.1 CORRECT FORMULATION

The former IUESIPS high dispersion correction formula for the echelle blaze is a parameterized sinc function of the form

$$\frac{\sin(X) \times \sin(X)}{X \times X} \times (1 + A \times X \times X)$$

where

$$X = Pi \times M \times (\frac{Lambda}{Lc} - 1)$$

M being the order number and Lc being the central wavelength corresponding to the peak of the blaze.

The parabolic factor was introduced when the observed blaze function was found to be broader than the theoretical sinc. Ahmad (1981, NASA IUE Newsletter No. 14) suggested that the ripple function could be better represented by a modified sinc function without a parabolic correction:

$$\frac{\sin(0.85 \times X) \times \sin(0.85 \times X)}{0.85 \times 0.85 \times X \times X}$$

Ake performed a more exhaustive analysis of the blaze function from the theoretical form of the diffraction envelope produced by a perfect plane blazed grating used in high orders. His conclusions were that the definition of X was incorrect in a minor way and that the formulation by Ahmad of the actual blaze function is the more appropriate functional form. In addition, he found empirically that the value of K (M x Lc, commonly referred to as the grating constant) was not a constant for the grating, but varied with order number. This result could not be substantiated with a theoretical derivation. The result of this analysis was

$$X = \mathrm{Pi} \times M \times A \times \left(1 - \frac{Lc}{\mathrm{Lambda}}\right) = \mathrm{Pi} \times A \times \left(M - \frac{K}{\mathrm{Lambda}}\right)$$

and the ripple correction is

$$\frac{\sin(X) \times \sin(X)}{X \times X} = \mathrm{sinc}(X) \times \mathrm{sinc}(X)$$

where A is a correction factor similar to Ahmad's 0.85 constant and K is the grating constant M x Lc.

4.4.2 ORDER DEPENDENCE

The work done by Ake (NASA IUE Newsletter No. 19) has shown that the grating constant, K, is not a constant but rather can be represented by a function of the order number, M. By fitting the observed energy distribution of standard stars observed with the IUE in high dispersion, a table of K values versus order number can be developed. One would expect such a table to be smooth, but the fitting procedure results in a noisy relation due to the instrinsic features within the spectrum and the noise in the data. To reduce the fits to a smooth function the results have been approximated by a second order polynomial. The results for the currently operational cameras are:

$$\text{Correction} = \text{sinc}(\ \text{Pi} \times A \times (M - \frac{K}{\text{Lambda}}))\ {**}\ 2$$

where M is the order number, and A and K depend on the camera.

For the LWR camera:

$$K(\text{LWR}) = 230036. + 15.3456 \times M - 0.050638 \times M \times M$$
$$A(\text{LWR}) = 0.89$$

where the wavelengths are air wavelengths (standard IUESIPS output longward of 2000 Angstroms).

For the SWP camera:

$$K(\text{SWP}) = 138837. - 27.426 \times M + 0.165883 \times M \times M$$
$$A(\text{SWP}) = 0.86$$

Ake has pointed out that these corrections should be applied to the observed wavelengths corrected for shifts within the cameras (see the section on dispersion constants) but not corrected for the radial velocity shifts.

4.4.3 TIME DEPENDENCE

During the derivation of the echelle ripple constants presented in the previous sections, spectra from the entire lifetime of IUE were examined. In order to ensure a stable wavelength scale the data set was reprocessed with the current IUESIPS software. Nonetheless, there appear to be differences between various LWR images taken at different times. This change in the K value appears to be order dependent.

At the present time the staff of the IUE observatory is interpreting these differences as a nonuniform change in the photometric properties of the LWR camera, which results in an apparent change in the shape (hence the ripple function) of the orders in high dispersion. For this reason, it is not obvious that any change in the ripple function is the appropriate correction for this change in the camera performance. The SWP camera does not show these same effects.

4.5 BACKGROUNDS

IUE backgrounds can be categorized into two types: those that affect the entire image and those that affect the spectral region only. Those backgrounds which affect the entire image are corrected for in the normal IUE processing system by selecting a background region outside the spectral format and using the values found there as representative of the background under the spectral data. So long as the variations in the background have a spatial extent large compared to the distance between the data and the area selected to sample the background, this correction method should be adequate.

Four backgrounds have been identified as having characteristics unfavorable to the IUESIPS form of correction: camera defects, halation, grating scatter and geocoronal Lyman

Alpha emission. The current state of our understanding of these problems is summarized in the following sections.

4.5.1 CAMERA DEFECTS

Several observers have examined the camera backgrounds obtained during long exposures by exposing both cameras at the same time: one on the target and one on the sky. An analysis of these images shows that in addition to the large-scale background features and the radiation-induced hot spots (hits), the cameras suffer from bright spots which have sizes and intensities ranging from those of hits (such as the bright spot in the LWR low dispersion specra at 2190 Angstroms) to those of weak spectral features. Davidson et al , (1982, ApJ, 253, 696) reported that they were able to eliminate the effects of some of these features by constructing a median background image from six sky exposures.

At the present time, the IUE project is investigating further ways to establish a "standard" background image which can be used to correct for these blemishes. There are no simple correction techniques that can be used due to the inability to distinguish camera defects from radiation events.

4.5.2 HALATION

A second background which is not properly corrected by the default IUESIPS processing is halation in the image converter. This halation appears as a spreading of the image. Prelaunch testing indicates approximately ten percent of the incident radiation is scattered by halation. This effect has been reported by a number of IUE observers as "wings" on the point spread function. The halation is a long range phenomenon compared to the point spread function, but short range compared to the total image size (approximately 17 pixels half width according to an internal IUE report).

The effects of halation on the data are two fold: the point spread function is wider than the nominal extraction slits which means that the instrumental calibration only applies to data extracted in the same manner as the calibration observations, and the light scattered into the background is incorrectly subtracted from the gross data. The problem with the calibration is not a major effect, however, it does mean that using very narrow extraction slits (as has been recommended by several users to improve the signal-to-noise ratio) can underestimate the total flux by as much as 10-15 percent. The light being scattered into the background areas is a minor effect for the low dispersion data and is the cause of the "order overlap" problem seen in the high orders of the high dispersion spectra.

At the present time, the most hopeful correction technique appears to be a filter applied to the image before extracting the data. This technique is expected to require substantial computational time. Nonetheless, experimental evaluations of this filter are in progress by the IUE project. Recently Bianchi and Bohlin (1982, preprint) have been suggested that the line depths measured by Copernicus and IUE for strong lines could be used to derive an empirical ex post facto correction for the net flux in the high dispersion.

4.5.3 GRATING SCATTERED LIGHT

The spectrograph gratings scatter light in the direction of the dispersion. For low dispersion SWP spectra, the effect of this scattering is the detection of flux shortward of 1100 Angstroms. Since the windows of the IUE cameras are not transparent shortward of 1100 Angstroms), the flux seen at these wavelengths must be due to longer wavelength photons scattered by the grating.

Several attempts have been made to model this grating scattering by convolving the camera response functions with the incident flux distributions. It appears from the two studies reported in the IUE Newsletters (Stickland, 1980, ESA Newsletter No. 6, and Clarke, 1981, NASA IUE Newsletter No. 14) that for stars of spectral type F through K most of the scattering comes from the 2700-3200 Angstrom region. Clarke reports that the corrections for the SWP camera derived by this convolution technique appear to have a reasonable shape but are not accurate in value.

4.5.4 GEOCORONAL LYMAN ALPHA

The only sky background emission line which is seen with the IUE is geocoronal Lyman Alpha. This line arises from hydrogen within the vicinity of the Earth. For high dispersion spectra the influence of this line is minimal, as the dispersion is so large. In low dispersion when spectra are taken through the large aperture, the geocoronal emission can mask the information within the region of Lyman Alpha.

To attempt to correct for this emission, the Europeans have built a model for the observed Lyman Alpha emission for both the large and small apertures from nine sky observations (Ponz and Penston, 1982, NASA IUE Newsletter No. 19). This model is then fit to the portions of the line-by-line spectra which do not contain the observed object (i.e., the large aperture for small aperture exposures and the small aperture for large aperture exposures) and subtracted from the line-by-line file.

SECTION 5 - SIGNAL-TO-NOISE RATIO

The techniques and corrections discussed in the previous sections will give improved values for the wavelength and flux scales. However, the measurement of quantities of astrophysical interest (e.g., equivalent widths and radial velocities) depend on the signal-to-noise ratio of the data as well. This section discusses techniques for improving the signal-to-noise ratio. Several techniques can be used to optimize the signal-to-noise ratio of individual spectra. IUESIPS already uses some of these techniques (e.g., the median filtering of the background); however, careful consideration of each exposure can improve on the default processing. In addition, the characteristics of averaging spectra to improve signal-to-noise ratio are discussed.

5.1 OPTIMUM EXTRACTION SLITS

The IUE cameras produce a substantial amount of readout noise. This readout noise is dominated by photon noise for exposure levels near 200 data numbers (DN), but dominates the weaker portions of the image. For this reason, it is important when extracting the data from the image to use an extraction slit which includes the data and excludes as much background as possible. In the discussion on backgrounds, the point was made that the slit must be long enough to include the entire point spread function, if accurate, fluxes are to be determined. For this reason, IUESIPS uses slit heights which are optimized to determine the flux in the presence of minor errors in registration with the spectrum. One can extract with materially shorter slits if the registration can be checked and precise fluxes are not needed.

At the present time the defaults used by IUESIPS for low dispersion are:

Large aperture - Extended source = 15 diagonal pixels
Large aperture - Point source = 9 diagonal pixels
Small aperture - Point source = 9 diagonal pixels

The point spread function appears to have a variable width in both the low and high dispersions but the full-width-half-maximum (FWHM) is always less than 4 pixels (3 diagonal pixels) in conditions of good focus. In addition, the orders in all the cameras and dispersions are not well fit by the dispersion relation at the subpixel level. For these reasons, the shortest extraction slit which gives reasonable results is 7 pixels (5 diagonal pixels). Even so the flux might be systematically low with this length, particularly when telescope or spectrograph focus is poor. Shorter extraction slits can grossly underestimate the total flux due to the asymmetries in the point spread function (caused by the optics of the telescope and spectrograph), spreading caused by poor focus, local deviations of the order from the dispersion relation, and misregistration. In addition to errors in the total flux, the flux in sub-ranges of the spectrum will be in error by different amounts due to the non-global nature of the asymmetries and the deviations from the dispersion relation. Extraction slits with lengths of 10 pixels or greater (7 diagonal pixels) appear to be entirely adequate (better than 99 percent of the flux extracted by the standard processing) if the spectrum can be centered well.

From the results presented in the previous paragraph, re-extracting the data from the original image or the line-by-line spectrum can improve the signal-to-noise ratio of the data. This improvement is most dramatic for weak spectra where the readout noise dominates. In principle, using five lines of the line-by-line file to re-extract the gross flux could could reduce the noise in the spectrum by 25 percent as compared to the default point source extraction. In practice, about half this improvement can be routinely achieved. A secondary benefit for long exposures is the reduction of the number of particle blemishes in the extraction slit. This effect is proportional to the area of the extraction slit and so scales linearly with the height of the extraction slit. A five-line extraction from the line-by-line file would reduce the occurrences of particle blemishes by 45 percent from the default point source extraction slit. One should keep in mind that this improvement does cost both in the accuracy of the total flux and the accuracy of the gross structure of the spectrum.

5.2 FILTERING

A second technique for improving the signal-to-noise ratio of the spectra is to filter the data. In general, if the data and the noise possess different characteristic spatial frequencies, the judicious use of filtering can improve the signal-to-noise ratio by suppressing the noise without modifying the data.

Two forms of filtering appear to be most useful with IUE data: the suppression of noise and the removal of blemishes. To accomplish these ends requires different types of filters. The suppression of noise can be accomplished with simple filters such as a boxcar. These filters usually have the bad characteristic that some frequencies are much more heavy filtered than others, which makes determining a realistic signal-to-noise ratio of the result very difficult. The removal of blemishes is particularly difficult if filters which preserve the total signal are used. Originally IUESIPS filtered the backgrounds with a two pass boxcar, and often the results had broad peaks and dips corresponding to radiation hits and reseaux. Fortunately, other filters such as the median filter (which replaces the mid-point with the median of the data within the filter width) quite effectively eliminate this problem.

For IUE spectra, the filtering can be applied to either the data or the background. Since these processes have inherently different purposes they are discussed separately in the next two sections.

5.2.1 BACKGROUNDS

The backgrounds for IUE spectra are taken from portions of the image believed to contain no signal. To compute the net flux, this background is subtracted from the gross signal. If the noise in the background is comparable to the noise in the gross signal (which is true for weak exposures where the readout noise dominates), then the noise in the net flux will be 1:414 times larger. By filtering the background data before computing the net flux, this noise enhancement can be eliminated.

Currently, IUESIPS filters the backgrounds with a 63-point median filter followed by two passes of a 31-point boxcar. These filtering widths are wider than are necessary. Radiation blemishes are typically narrower than the instrumental resolution which is 5-7 samples with the current IUESIPS processing. Thus, any median filter width larger than 15 samples will effectively eliminate these blemishes. In addition, since the noise adds as the root-mean-square, reducing the noise in the background to one third that in the gross will degrade the signal-to-noise ratio by only 5 percent. Filtering with a boxcar filter will reduce the noise in the background by this amount with widths as narrow as 9-12 samples. Wider filters quickly reach the point of diminishing returns.

There is one additional consideration to filter widths. For low dispersion spectra taken in the large aperture, the IUESIPS processing takes the backgrounds eleven lines from the data in the line-by-line file. The lines in the line-by-line file are spaced 1:414 pixels or two samples apart. Since the data from either side of the data extraction area are averaged to set the background, IUESIPS has in effect assumed that no structure in the background less than 44 samples wide is real. Thus, it is consistent to filter the backgrounds with widths comparable to 44 samples. Somewhat smaller numbers apply to small aperture or high dispersion spectra because the backgrounds are taken closer to the data. Filtering with widths larger than the separation of the backgrounds may compromise the data by removing structure from the background which is real.

5.2.2 SPECTRA

Whereas filtering the backgrounds merely protects the signal-to-noise ratio from degradation during the computation of the net flux, filtering the spectrum can improve the apparent signal-to-noise ratio. Unfortunately, for this filtering to be valid the characteristic spatial frequency of the spectral data must be significantly different from that of the noise. When this condition is not valid, filtering will modify the spectral information and possibly the resulting interpretation of the data. Normaly the noise is shot noise, which covers all spatial frequencies equally. Filtering of data containing shot noise can do little more than improve the appearances of the data. This improvement is misleading as the noise at the spatial frequencies of the spectral data is still unchanged.

By design, the IUE data are sampled such that the spectral data exist at all spatial frequencies validly represented in the data. Thus, only spectral data which do not make use of the resolution of the instrument can be meaningfully filtered. Two sorts of data fulfill this requirement; spectra with intrinsically wide features and spectra which have been widened normal to the dispersion. In each case the appearance of the data, and the occurrence of blemishes with widths near the resolution (e.g., radiation "hits") can be improved by filtering. In each case, the filtering should be applied only so that the redundant information is filtered. Thus for widened spectra the filtering should be applied to the line-by-line file in the direction normal to the dispersion. However, studies of the instrumental reproducibility have shown that averaging the data into large bins does not improve the statistics of the data in a manner indicating random noise. For this reason, the improvement in signal-to-noise ratio which is gotten from filtering may be apparent, rather than real. This fact does not invalidate filtering with an appropriate median filter to remove the effects of radiation blemishes and reseaux.

With the implementation of the new processing software (November 1980 for low dispersion and November 1981 for high dispersion), the situation with respect to filtering IUE data changed. The primary change in the IUE output products was a decrease in the sampling interval used during the extraction process. In effect, the current IUESIPS results are oversampled by several times (a resolution element is now 5 to 7 samples). Analysis of high dispersion spectra has shown that the noise is not shot noise and the characteristic spatial frequency of the noise is different than that of the spectral data. For this reason, it is practical to filter the current high dispersion spectra in order to improve the signal-to-noise ratio. Simple filters such as a two- or three-point boxcar could be used, but they suffer from over-filtering the high spatial frequencies so that the resulting apparent signal-to-noise ratio is higher than the real signal-to-noise ratio. IUESIPS filters the net ripple-corrected record and the CalComp plots with filters which produce a realistic apparent signal-to-noise ratio. These filters are listed in Table 5-1 for the operational cameras. The corresponding filter values for the other cameras are undefined at this time.

Table 5-1. Minimal Noise Filters

Element	LWR	SWP
	0.0016	-0.0021
	0.0018	-0.0060
	0.0602	0.1017
Center	0.8728	0.8128
	0.0602	0.1017
	0.0018	-0.0060
	0.0016	-0.0021

Filtering the high dispersion data with these filters should improve the apparent signal-to-noise ratio by approximately 30-50 percent and make the noise resemble shot noise. This second feature of these filters allows one to use the sample-to-sample variations in the data to predict the amplitude of noise at other spatial frequencies.

5.3 AVERAGING SPECTRA

A third technique for improving the signal-to-noise ratio of the data is to average multiple exposures. So long as the noise is random, the signal-to-noise ratio should improve with the square root of the total accumulated exposure. However, the presence of fixed-pattern noise prevents this improvement as the noise will average in the same manner as the data. It is known that the SEC cameras are very prone to fixed-pattern readout noise, which can dominate the other noise sources (such as photon noise). IUE's cameras are dominated by photon noise for exposure levels near optimum (200 DN). In order to improve the signal-to-noise ratio, the spectral features must be aligned so that they will be correlated or else they will average out like the noise. Thus the first step in any averaging process must be to align the wavelength scales (see Section 3).

Several studies have been made of the effects of averaging spectra: Clarke, 1981, NASA IUE Newsletter No. 14, West and Shuttleworth, 1981, ESA IUE Newsletter No. 12, and IUE Observatory internal memos. All of these studies agree. If the data span a significant time so that the cameras, the temperatures or the radial velocity have changed, the averages will reduce the noise to a limit of 3 percent. This finding agrees well with the sensitivity monitoring results, which indicate that individual spectra taken significantly apart in time show approximately 5 percent nonreproducibility per sample whereas spectra taken within several days of each other reproduce to 3 percent per sample. This result is interpreted to mean that the total noise in a single image is approximately 5 percent (signal-to-noise ratio of 20) of which there is a nonreducible noise component of approximately 3 percent (signal-to-noise ratio of 33). The source of this nonreducible noise is not known at this time.

APPENDIX A - SCALE FACTOR RECORD

The contents of the first record of the extracted spectra files is cataloged in this appendix. The format presented is that in use at the RDAFs rather than the IUESIPS tape format.

FORMAT OF RECORD ZERO OF EXTRACTED SPECTRAL FILES AFTER 3 NOV. 1980

WORD (Integer*2)	QUANTITY
0*	No. of bytes per record
1*	No. of samples per record
2*	Number of orders present
3*	Camera Number
4*	Image Number
5*	Number of records per group (i.e. per order)
6	Year
7	Day Number - of Midpoint of Observation (GMT)
8	Hours - " " "
9	Minutes - " " "
10-13	Date as above for Time of Image Processing (GMT)
14	Target Aperture (1-large, 2-small)
15	Total line shift (pixels x 1000)
16	Total sample shift (pixels x 1000)
17	THDA X10 (degrees centigrade) at time of read
18*	Minimum FN for Gross
19*	Maximum FN for Gross
20*	J for Gross - where actual FN = data on
21*	K for Gross Tape x J x 2**(-k)
22-25*	as in 18-21 for Background
26-29*	as in 18-21 for Net
30-33*	as in 18-21 for Absolute Net
34-38*	Spares
39-41	Min, Sec, ms of exp in Target Aperature
42	Hours - Right Ascension of Target
43	Minutes " "
44	Seconds x 10 " "
45	Degrees - Declination of target
46	Arc Minute " "
47	Arc Second " "
48-50**	VXsun,VYsun,VZsun - Velocity of earth in celestial coordinates (km/s x 10)
51-53**	VXsat,VYsat,VZsat - same as 48-50 for IUE at Midpoint of Exposure
54**	Net velocity toward target (km/s x 10)
55	Omega angle (degrees x 10);(zero in High Dispersion)
56	Wavelength Scaling Factor (= 5 for Low Dispersion, = 500 for High Dispersion) where actual wavelength = (wavelength on tape)/(Scale Factor) + offset wavelength
57	Background Slit Height - Low Dispersion only (pixels X 100)
58	Background distance from dispersion line (pixels X 100)
59	Dispersion Constant Shift (0 = no shift, 1 = auto shift, 2 = manual shift)

* Existing Quantity
** High Dispersion after 10 Nov 1981 Only

60	Bright Spot Removal Threshold DN for weak, long exposures (to be implemented)
61	THDA x 10 at the end of exposure
62-69	Spares

------IUE-RDAF Header elements------

70	Number of files coadded
71-85	Image numbers of the files coadded
86	Center of low dispersion extraction from line by line file (between 1 and 55)
87	Background smoothing parameter (mean filter width)
88	Background smoothing parameter (median filter width)
89	Camera 3 photometric correction algorithm (0=original, 1=SWPFIX, 2=QUADFIX)
90	Absolute sensitivity correction curve (0=no absolute calibration, 1=sensitivity curve in IUE Newsletter 10)
91	Extinction curve used (0=no extinction correction, 1=Savage and Mathis, Annual Reviews, 1979)
92	Value of E(B-V)*1000 used to correct for interstellar extinction
93	Scaling factors (0=original, 1=new; used when operating on a file by a constant)
94-96	Spares
97	K-K0 echelle ripple correction K0=137725 SWP K0=231000 LWR
98	A*1000 IUESIPS echelle ripple fudge factor
99	A*1000 Ahmad echelle ripple fudge factor

100-199*	Offset wavelengths for each order
200-299*	m, order number for each order
300-399*	Number of extracted data points in each order
400-499*	Slit height for each extracted order (pixels*100)
500	Sign + First 4 digits after decimal of dispersion constant A1
501	Sign + Second set of 4 digits after decimal of dispersion constant A1
502	Sign + Third 4 digits after decimal of dispersion constant A1
503	Exponent (including Sign) of dispersion constant A1 where: A1 = [word(500x10E-4+word(501)x10E-8+word(502)x10E-12]x10**(word(503))
504-507	As above, for dispersion constant A2
508-535	As above, for dispersion constants A3 through A9
536-571	As above, for dispersion constants B1 through B9
572-1021	Spares

(2 pages of tables)

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APPENDIX B - SCIENCE HEADER

This appendix contains the listing of a sample IUE Science Header as generated by the operations software at GSFC. Lines 3-9 are structured somewhat differently for European observations but contain the same information.

```
                    0001000100072048   1 1 013114483            1  C
  3078*   4*IUESOC  *   *   *   611*     *   *  * * * * * *    *  2  C
SWF 14483, HD 93632, 250 SEC, LARGE APER TRAIL,LOW DISP             3  C
 TRAIL RATE: 0.08 ARCSEC/SEC                                        4  C
                                                                    5  C
PROGRAM: RPSTD, OBSERVER: SCHIFFER, DATE:1981/196                   6  C
                                                                    7  C
                                                                    8  C
                                                                    9  C
81196192341* 9   * 218 *OPSDEV25*192050 FIN 2 T 509 S 98 U 109   * 10  C
180044 MODTIME 2 0 0           *192158 TARGET FROM LWLA          * 11  C
180110 FIN 2 T 690 S 98 U 109  *192241 ITER 1 TIME  .200000E 03 * 12  C
180531 TLM,SWPROM              *192309 TLM,SWPROM                * 13  C
180613 READPREP 3 IMAGE 14482  *192342 READPREP 3 IMAGE 14483    * 14  C
180651 SCAN READLO SS 1 G3 44  *192420 SCAN READLO SS 1 G3 44    * 15  C
180705 X 60 Y 76 G1 82 HT 105  *192436 X 60 Y 76 G1 82 HT 105    * 16  C
182704 TLM,LWRROM              *192413                           * 17  C
182802 READPREP 2 IMAGE 11067  *192434                           * 18  C
182953 SCAN READLO SS 1 G3 58  *171542 TLM,FES2ROM               * 19  C
183012 X 56 Y 72 G1 99 HT 106  *171713 FESIMAGE 0 0 31           * 20  C
185010 TLM,FES2ROM             *172057 MODE SWL                  * 21  C
185120 TRAIL 3  .800000E-01    *172123 MODE LWL                  * 22  C
185255 TARGET IN SWLA          *172259 TRAIL 3  .500000E-01      * 23  C
185458 EXPOBC 3 25 0   MAXG NOL *172431 TARGET IN SWLA           * 24  C
190511 MODTIME 3 0 0           *172645 EXPOBC 3 25 0   MAXG NOL * 25  C
190543 FIN 3 T 610 S 97 U 109  *174152 MODTIME 3 0 0             * 26  C
190651 TARGET FROM SWLA        *174223 FIN 3 T 903 S 97 U 109    * 27  C
190743 ITER 1 TIME  .250000E 03 *174335 TARGET FROM SWLA         * 28  C
190802 TRAIL 2  .100000E 00    *174416 ITER 1 TIME  .400000E 03 * 29  C
190937 TARGET IN LWLA          *174502 TRAIL 2  .710000E-01      * 30  C
191147 EXPOBC 2 25 0   MAXG NOL *174625 TARGET IN LWLA           * 31  C
192019 MODTIME 2 0 0           *174907 EXPOBC 2 25 0   MAXG NOL * 32  C
                                                                   33  C
                                                                   34  C
                                                                   35  C
RPSTD*1*04*SCHIFFER        *   *   *H*   93632* *0* * 12           36  C
1045155-594959*  0*04* *8.34*+0.32*        *   *       *   *       37  C
                                                                   38  C
                                                                   39  C
```

****

Lines 40 though 71 deleted for brevity

****

```
                                                                   72  C
                                                                   73  C
                                                                   74  C
                                                                   75  C
  5      ‡ H  ˝   +     +     >   i5   :‡ ˝ @            t         76  C
      [] u                   ? ′ ‡ @ ‡  ■ k ■ n o      -  7        77  C
@ ‡ ‡ ‡‡‡‡‡    ' ` [: kl| ■{' e                ] A5 bb   bb        78  C
   A2 ca                    h f , % ,‡ =′':;  ′'= +b               79  C
     i                                                             80  C
        +                                                          81  C
| -                                                                82  C
                                                                   83  C
                                                                   84  C
```

```
                                                         85  C
ir-             ? A5 bb   bb^ %     /           =        86  C
i                 A5   \RR    %     /                    87  C
io-               B2 ca    '@'::    /                    88  C
im                A2 ca     '':     /                    89  C
iP  -          ]  A5 bb   bb% ,‡ =  /                    90  C
iQ-               A5 bb   bb% ,: '  /                    91  C
i -              QE1 *   G:k= :      `                   92  C
i -     /         A2 ca     ' ‡     /                    93  C
io-               A6 bb   bb> %: '  /                    94  C
i -     $        QE1     F k' :      `                   95  C
i -               A2 ca     @ :     /                    96  C
i -            [_ A2 ca     : :     /                    97  C
i       `        QB1     Na   :                          98  C
ir  -   `         D5s   R   > %     /  `                 99  C
i -     (      ]  A5 bb   bb% %     /                   100  C
```

(2 pages of tables)

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APPENDIX C - PROCESSING HISTORIES

The processing history is appended to the Science Header during the processing by IUESIPS. Listings of sample low and high dispersion processing histories are included in this appendix.

Low Dispersion

```
***** SCHEME NAME:  T3LTAC *****                                        C
PCF C/** DATA REC. 11 1    1    1 768 8448 5 3   6.1   5.0 2536    .00000 1PC
          0         1684        3374        6873        9091        10586   1PC
     14371        17745       21524       25105       28500                 1PC
    11.000       11.000      11.000      11.000      11.000      11.000     1PC
    11.000       11.000      11.000      11.000      11.000                 1PC
TUBE   3 SEC EHT  6.1 ITT EHT  5.0 WAVELENGTH 2536 DIFFUSER 0               1PC
    C      MODE : FACTOR   .178E 00                                         1PC
*PHOTOM   09:34Z JUL 16,'81                                                 HC
********  DATA FROM LARGE APERTURE ********                                  C
*SPECLO   09:34Z JUL 16,'81                                                 HC
OBSERVATION DATE(GMT): YR=81  DAY=196  HR=19  MIN= 1                         C
TARGET COORD (1950) :  RT. ASC.=10 45 15.5  DECL.=-59 49 59                  C
OPTIONS :HT=15,  HBACK=  5,  DISTANCE= 11.0,  OMEGA=  90.0                   C
MEAN RESEAU  (GMT= 78.085-79.334 NO. FF= 18 SIGS= .134 SIGL= .138 PX)  C
MEAN DC  (GMT= 79.091-81.032  NO. WLC=  40  SIGS= .263 SIGL= .252 PX)  C
B 1= -.282589828821D 03 B 2=  .376206277037D 00 B 3=  .000000000000D 00C
A 1=  .966679562841D 03 A 2= -.466519276822D 00 A 3=  .000000000000D 00C
THDA FOR RESEAU MOTION =  7.16                                               C
THDA FOR SPECTRUM MOTION =  7.16                                             C
THERMAL SHIFTS:   LINE =  -.097   SAMPLE =  1.258                            C
REGISTRATION SHIFTS:   LINE =   .707  SAMPLE =   .570   AUTO                 C
*POSTLO   09:34Z JUL 16,'81                                                 HC
****MERGED SPECTRA- GROSS, BACKGROUND, NET, & ABS. CALIB. NET                C
*ARCHIVE   09:34Z JUL 16,'81                                                HL
```

High Dispersion

```
**********  RAW IMAGE **********                                            C
*ARCHIVE   19:37Z FEB 18,'80                                                HC
*MICRO   16:33Z NOV 13,'81                                                  HC
***** SCHEME NAME:  T3HLAC *****                                             C
PCF C/** DATA REC. 11 1    1    1 768 8448 5 3   6.1   5.0 2536    .00000 1PC
          0         1684        3374        6873        9091        10586   1PC
     14371        17745       21524       25105       28500                 1PC
    11.000       11.000      11.000      11.000      11.000      11.000     1PC
    11.000       11.000      11.000      11.000      11.000                 1PC
TUBE   3 SEC EHT  6.1 ITT EHT  5.0 WAVELENGTH 2536 DIFFUSER 0               1PC
    C      MODE : FACTOR   .178E 00                                         1PC
*PHOTOM   16:33Z NOV 13,'81                                                 HC
********  DATA FROM LARGE APERTURE *****************                          C
*SPECHI   16:33Z NOV 13,'81                                                 HC
MEAN RESEAU  (GMT= 78.085-79.334 NO. FF= 18 SIGS= .134 SIGL= .138 PX)  C
MEAN DC  (GMT= 79.091-81.032  NO. WLC=  41  SIGS= .204 SIGL= .231 PX)  C
B 1= -.658577715473D 04 B 2= -.127092427525D 00 B 3=  .125533624294D-05C
B 4=  .000000000000D 00 B 5=  .407922452809D 00 B 6=  .172022377821D-07C
B 7= -.237700930454D-06 B 8=  .000000000000D 00 B 9=  .000000000000D 00C
A 1=  .963776535232D 03 A 2= -.177605064866D 00 A 3=  .129246425786D-05C
A 4=  .313148250187D-01 A 5= -.465498655399D 00 A 6= -.226814749602D-06C
A 7= -.143951757346D-07 A 8=  .000000000000D 00 A 9=  .000000000000D 00C
THDA FOR RESEAU MOTION =  9.17                                               C
THDA FOR SPECTRUM MOTION =  9.17                                             C
THERMAL SHIFTS:   LINE =   .230   SAMPLE =   .051                            C
```

```
REGISTRATION SHIFTS:   LINE =   .066  SAMPLE =  -.084   AUTO          C
***** EXTRACTED SPECTRUM FOR POINT SOURCE ****                        C
*SORTHI   16:33Z NOV 13,'81                                           C
OBSERVATION DATE(GMT): YR=80  DAY= 48  HR=23  MIN= 5                  C
TARGET COORD, (1950):  RT. ASC.=13 45 34.3  DECL.= 49 33 44           C
IUE VELOCITY (KM/S):     VX= -2.8  VY=  1.8  VZ= -1.3                 C
EARTH VELOCITY (KM/S):   VX=-16.1  VY=-23.4  VZ=-10.1                 C
NET VELOCITY CORRECTION TO HELIOCENTRIC COORD.=  8.4                  C
*ARCHIVE   16:33Z NOV 13,'81                                         HL
```

(2 pages of tables)

C-2, C-3

Low Dispersion
(in units of 10-14 Ergs/cm2/A/sec/FN)

LWR Camera

Wavelength	1/S
1850	15.0:
1900	5.2
1950	3.0
2000	2.04
2050	1.77
2100	1.65
2150	1.61
2200	1.54
2250	1.32
2300	1.10
2350	.90
2400	.76
2450	.63
2500	.54
2550	.47
2600	.42
2650	.38
2700	.35
2750	.34
2800	.34
2850	.35
2900	.38
2950	.43
3000	.51
3050	.64
3100	.91
3150	1.4
3200	2.3:
3250	4.2:
3300	8.9:
3350	19:

SWP Camera

Wavelength	1/S
1150	20.7:
1175	7.92:
1200	4.34:
1225	2.92:
1250	2.41
1275	2.24
1300	2.18
1325	2.19
1350	2.26
1375	2.40
1400	2.60
1425	2.80
1450	3.04
1475	3.30
1500	3.54
1525	3.74
1550	3.84
1575	3.70
1600	3.50
1625	3.32
1650	3.12
1675	2.92
1700	2.73
1725	2.54
1750	2.36
1775	2.20
1800	2.10
1825	2.06
1850	2.04
1875	2.04
1900	2.03
1925	2.02
1950	2.02
1975	2.00

: Uncertain Value

High Dispersion
(Relative to Low Dispersion)

LWR Camera Wavelength	1/S	SWP Camera Wavelength	1/S
1925	292	1250	230
1950	259	1275	208
1975	229	1300	193
2000	207	1325	176
2025	191	1350	163
2050	180	1375	152
2075	171	1400	143
2100	165	1425	136
2125	159	1450	131
2150	153	1475	126
2175	149	1500	122
2200	143	1525	118
2225	139	1550	114
2250	136	1575	110
2275	132	1600	108
2300	129	1625	105
2325	126	1650	103
2350	122	1675	101
2375	120	1700	100
2400	118	1725	98
2425	116	1750	96
2450	115	1775	94
2475	114	1800	92
2500	113	1825	90
2525	112	1850	88
2550	110	1875	86
2575	109	1900	84
2600	108	1925	82
2625	107	1950	81
2650	106	1975	80
2675	105		
2700	104.5		
2725	104.0		
2750	103.5		
2775	103.0		
2800	102.5		
2825	102.0		
2850	101.5		
2875	100.5		
2900	100.2		
2925	100.0		
2950	99.5		
2975	99.0		
3000	98.5		
3025	98.0		
3050	97.5		
3075	97.0		
3100	96.5		

(2 pages of tables)

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