Summary of IUE Instrument Signature

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ABSTRACT

The available information on the IUE instrument signature and its impact on science data is summarized. Those interested in the details of IUESIPS should consult Turnrose and Thompson (1984). The space craft status (as of July 1985) is summarized by Faelker (1985). This report presents only the preliminary evaluations of any changes in the instrument signature which may have been introduced by the change to the 2 gyro + FSS control system effective 1985 August 17.

I. The IUE Calibration Philosophy

The IUE detectors are SEC Vidicon cameras, with ultraviolet converters to provide their UV sensitivity. Typical reduction steps involved in processing the raw data are:

- geometric correction (either explicit or implicit)
- application of the Intensity Transfer Function (ITF) which performs the linearization and flat-field corrections
- spectral extraction and background subtraction
- assignment of a wavelength scale to the extracted spectrum
- assignment of absolute fluxes
- compensation for artifacts

These steps are summarized below. The reader is referred to the Image Processing Manual (Versions 1.1 and 2.0) for details.

Geometric correction of IUE images is required because the "pixels" which are read out are not discrete elements, but are read-beam locations on the camera target. Because the pointing of the read-out beam varies with temperature and local exposure levels, the raw data must be mapped to a geometrically-correct domain before the other corrections may be applied. The reseau grid permanently fixed on the camera faceplate is used to define the correct geometric format. Images processed prior to the end of 1980 (GSFC low dispersion), 1981 (GSFC high dispersion) or 1982 March (VILSPA low and high dispersion) have been explicitly geometrically corrected. Since the explicit geometric correction resamples the data, more recently processed images are not explicitly corrected. Instead the ITF data are mapped onto the image in a geometrically correct manner. At present only calibration images such as the UV flood flat-field images used to derive the ITF and the Pt-Ne lamp spectra used to derive the dispersion constants are explicitly corrected.

The data must then be linearized and flat-fielded. This reduction is accomplished by the application of the ITF. The ITF is derived from a set of UV-flood lamp flat-field images of varying exposure level. The ITF is normally constructed by averaging several (1 to 5 images in early ITFs) individual flat-field images for each of 11 or 12 exposure levels. The linearization function is then derived for each pixel in the geometrically-corrected image. A source of error in the ITF is caused by the spatial registration uncertainty of 0.2 pixels for any two images (Turnrose and Thompson 1984). This registration uncertainty affects the ITF in the geometric correction of the individual flat field images, the generation of average flat field images at each intensity level in the ITF, and the mapping of the final ITF dataset to match the format of the raw spectral image of interest. Analysis of ITF images has shown that while the ITF does a good job of removing the large scale sensitivity variations in the IUE cameras, the smoothing inherent in the generation of the ITF means that essentially no compensation for pixel to pixel sensitivity variations is made. Linearity errors, or failures of the ITF to compensate for the non-linear response of the cameras to incident light, and the signal to noise characteristics of the extracted spectra will be discussed below. Since the ITF flat field images have short exposure times, they do not show the camera artifacts which become apparent at long exposure times, and thus do not correct for them (Hackney, Hackney, and Kondo 1985).

Wavelength calibration is done by finding the positions (line and sample) of Pt emission lines in the geometrically-corrected wavelength calibration image. The coefficients of the analytic relation between order number and wavelength and line and sample coordinates are the dispersion constants. In practice, mean dispersion constants corrected for the time and temperature of the observation are applied to image data since this minimizes extraction and random errors. When mapped back into the raw image coordinate system, the dispersion constants are used to control the assignment of wavelengths to the extracted spectral data.

Once the dispersion relations are known, the positions of the order(s) in the geometrically corrected reference frame must be found. The wavelength scale must be registered with the spectrum, which may be offset either accidentally or as part of the observing program. To extract each order, the dispersion relations must be mapped back into the photometrically corrected raw image space. For low dispersion images the mapping is done for each pixel. In high dispersion, due to the sheer volume of data, the mapping is done for selected pixels, and the position of the order between these points is determined by bilinear interpolation between the mapped pixels.

Low-dispersion spatially-resolved extracted spectra are generated by passing a numerical slit along the dispersion direction, and calculating the extracted flux values every $\sqrt{2}/2$ pixels along and approximately perpendicular to the dispersion direction. In the older software, the slit was $\sqrt{2}$ pixels wide. Extracting data from the image in this way is equivalent to forming an appropriately weighted average of the four surrounding pixels for each pixel in appropriate portion of the photometrically corrected image. For large aperture observations size of the extraction slit in the spatial dimension is controlled by the extraction type, such as point source, trailed, or extended source extraction selected by the observer (unless the image has been reprocessed). The extraction of fluxes in the spatial direction is along lines of constant wavelength which make an angle ω with the dispersion direction. Turnrose and Thompson (1984, page 7-15 and following) give the ω s for point source, extended source, trailed and small aperture observations. For images processed prior to 1 October 1985, 110 lines are extracted in the spatial direction and averaged in pairs to produce the 55 line spatially-resolved image file (see Munoz Peiro, 1985 for details). Images processed after this date will omit the pair-wise averaging and will have spatially resolved spectral files which have 110 lines. Gross slit-integrated spectra are formed by adding 9 (point source) or 15 (extended source) lines of the spatially resolved data. Background spectra are produced by summing 5 adjacent lines on each side of the gross spectrum, filtering them, averaging them, and normalizing the averaged background spectrum to the size of the gross spectrum extraction width. Point source backgrounds are offset from the gross spectrum by $8\sqrt{2}$ pixels in the spatial direction, while extended source backgrounds are offset by $11\sqrt{2}$ pixels. Flagged data are excluded from the averaging in forming the background but not the gross spectra. While it is possible to sum a smaller number of lines to form a gross spectrum for most low dispersion spectra, the resultant fluxes may be systematically low by 10-20% due to neglect of the far wings of the IUE point spread function where camera halation dominates.

The high-dispersion extraction does not include a spatially resolved file. Gross spectra are formed by passing a numerical slit along the measured and interpolated positions of the orders. The gross extraction slit width varies as a function of order number across the high dispersion image. The background (inter-order) spectra are extracted by passing a slit one square pixel in area halfway between successive orders, and averaging the inter-order spectra on each side of the order of interest.

The absolute calibration, or conversion of linearized FN to flux units such as ergs/ cm^2/s/A is derived from observations of standard stars which have been previously observed by absolutely calibrated rocket experiments and satellites. The uncertainty in the absolutely calibrated fluxes is due to the uncertainties in the absolute fluxes assigned to the standards (5-10%), the signal-to-noise characteristics of the calibration spectra, ITF linearity errors, and the resemblance of the source spectrum to the calibration spectra.

The results of the wavelength calibration and the absolute calibration are most visible to users of IUE data. It is important to keep in mind that the accuracy and validity of these calibrations are closely tied to the calibration data used to derive the calibrations and to the algorithms used in the reduction of both the science data and the calibration data. In particular, the absolute calibration is closely tied to the ITF dataset used to linearize the data, and the wavelength calibration is tied to the algorithm used to geometrically correct the wavelength calibration data and to distort the dispersion constants to match the spectral image distortion. The sections below will discuss aspects of the overall IUE instrumetation, calibration, and processing which affect the quality, accuracy, and reproducibility of the extracted IUE spectra.

II. Geometric Effects and Spectral Extraction

Shortcomings of the geometric correction affect extracted spectra by the presence of spectral extraction errors, and complicate the wavelength calibration. The first source of errors is in the mapping of the ITF data onto the raw spectral image. The mapping function, or inverse of the geometric distortion is determined by from mean reaseau positions in 60% UV flood images (mean DN=120) which are corrected for thermal effects for the SWP only. Small shifts of the reseaux grid as a function of camera temperature are known to exist for the LWR and LWP, but were sufficiently small that inclusion in the standard image processing was not justified. Nonetheless, these thermal shifts can introduce errors into LWR or LWP images, particularly those taken at extreme temperatures, since the mapping of the ITF onto the spectral image will be slightly off. The correct mapping from the ITF onto a spectral image also depends upon the DN levels in the image. Essentially any image which does not have a mean DN similar to the UV flood images will be affected by "beam pulling" since localized charges on the camera target will deflect the read beam.

The second step which can introduce errors into the extracted spectrum and its wavelength scale is the spectral registration step. In this phase of the image processing mean dispersion relations for the camera of interest are corrected for time and temperature (N.B. SWP and LWR images processed since June 1984 also are corrected for a second order time effect). Errors can be introduced if the temperature (THDA) for an image was unknown and the default temperature used in the dispersion relation. The corrected dispersion relations are used to predict the mean position of the spectrum in the photometrically corrected image. This step also determines the wavelength scale in each order. In general the spectrum does not lie at exactly the position predicted by the mean dispersion relations, and it is necessary to adjust the registration perpendicular to the dispersion before extracting the spectrum. The adjustment step may be done either automatically (if the spectrum has enough signal), manually, or not at all. In low dispersion, the automatic registration has errors from 0.1 to 0.3 pixels for a point source spectrum. Manual registration errors are larger, more difficult to predict, but are typically less than 0.5 pixel. In high dispersion the errors are more difficult to assess since the orders may be differentially displaced from the mean position (Thompson and Bohlin 1981). Any large error in the placement of the extraction slit can potentially result in corrupted gross and background spectra in the extracted spectral data. High dispersion spectra, especially in the high order numbers, are particularly sensitive to such extraction errors as a result of the crowding of orders in the echelle format (Grady 1980). For images processed since November 1981 (GSFC) or March 1982 (VILSPA) the dispersion constants have included time and temperature dependent terms which largely compensate for the spectral extraction errors. The image registration techniques have also been improved to minimize misregistration (Thompson and Bohlin 1981). Images processed prior to this date can have fluxes in error by 100% at the shorter wavelengths (Grady 1980). Signatures of extraction errors include the presence of spectral features in the nominal background spectrum, and net fluxes which go significantly below zero. A discussion of the order overlap problem in high dispersion is given by Bianchi and Bohlin (1983).

III. Linearity

The ITF does not perfectly linearize IUE spectra, resulting in small departures which are dependent upon the exposure level of the spectral image. To date most of the evaluation of departures from correct linearization, or linearity errors, has been done with low dispersion trailed spectra of a bright continuum source (HD 60753, a B3 star). An optimally exposed (100%) spectrum of this source has peak signal in the range of 200-220 DN. Spectra of objects having flux distributions differing significantly from this type and level of exposure may suffer from linearity errors of up to a few percent (Oliversen, 1984a, 1984b; Oliversen, 1983; Harris, 1984). Linearity effects in the background also affect the data quality. Linearity errors in the new LWR ITF are discussed in Oliversen (1984b).

Another source of error is extrapolation above the DN values in the ITF calibration images. Upper limits to the application of the ITF to high DN values are discussed in Turnrose, B.E. (1980), and Turnrose and Thompson (1984). A comparison of data linearized by extrapolation from the highest level in an ITF and the same data linearized with an ITF having an additional exposure level is given in Holm (1981).

The early ITFs used to linearize spectral data for each camera are known to contain errors. The initial ITFs used during the commissioning period for the SWP and LWR were composed of single UV flood images at each exposure level. The current LWP ITF is also composed of single UV flood images. The null level in this ITF is uncertain, and may result in line by line (low dispersion) files with negative FN in the background (Imhoff, 1985d).

An error in the construction of the SWP ITF affects early low dispersion spectra processed between mid 1978 to mid 1979. All high dispersion spectra from this period were reprocessed with the correct SWP ITF. Errors in early SWP spectra due to the bad ITF are discussed in Holm (1981b) and by Holm et al. (1982). Algorithms for correcting SWP low dispersion spectra processed between mid 1978 and mid 1979 are presented in Cassatella et al. (1980) and Holm and Schiffer (1980). An example of the problem caused by the bad SWP ITF is given in Imhoff and Grady (1985).

IV. The Wavelength Scale

Wavelength Resolution

The wavelength resolution for a given camera depends upon the dispersion, the aperture used for the observation, the wavelength range of interest, the telescope focus, and to a small extent the the processing system. For a discussion of the point spread function (PSF) in low dispersion see Cassatella et al. (1985). A summary of various studies of the PSF in high dispersion is given in section 2.3 of Turnrose and Thompson (1984), and by Evans and Imhoff (1985). Evans (1984) has shown in a comparison of Pt lines from wavelength calibration images and interstellar lines that the PSF in the dispersion direction for high dispersion is similar in both cases. Scott (1985) and Grady (1985) have shown that there is no degradation in the PSF perpendicular to or parallel to the dispersion direction in high dispersion images under the 2-gyro pointing control system.

Wavelength Accuracy

Once the spectra are extracted the wavelength scale is corrected for the change from vacuum to air wavelengths at 2000 A (LWR, LWP only), and the velocity of the spacecraft with respect to the sun. Wavelengths for early spectra do not have the heliocentric velocity correction. Errors in correctly accounting for the vacuum to air correction and the heliocentric velocity correction in archival spectra are described in Turnrose, Thompson, and Gass (1984).

The absolute accuracy of the wavelength scales in low dispersion are dependent upon the accuracy of the wavelength assignments to the Pt-Ne calibration lamp spectra, the extent to which the lamp spectra resemble actual astronomical spectra, the mapping from the small aperture to the large aperture, and the placement of the source in the aperture. The dominant source of uncertainty in large aperture spectra is in the target placement in the aperture. This can introduce offsets as large as 10 A, especially for spectra which were acquired using blind offsets. For brighter objects which are directly acquired, the typical centering accuracy is approximately one second of arc, translating into an uncertainty in the wavelength scale of 2.2 (SWP) or 2.4 (LWR) A in low dispersion (Harvel *et al.* 1979). Systematic errors in the wavelength calibration which are known to affect archival spectra are discussed in Turnrose, Thompson, and Gass (1984). For small aperture low dispersion spectra, the dominant source of uncertainty is in the wavelength calibration with the Pt-Ne lamp and in the mapping of the dispersion constants back to the reference frame of the observed data.

In high dispersion large aperture spectra, miscentering errors can introduce an uncertainty as large as +/-25 km/s into the wavelength scale (Engvold, et al. 1983). Small aperture SWP high dispersion spectra corrected for the velocity of the spacecraft have an uncertainty as low as 2.2 km/s rms (De la Pena and Ayres 1984). For LWR high dispersion spectra, the internal consistency of the wavelength scale is 2.7 km/s (Thompson et al. 1981, Turnrose and Thompson 1984). Heckathorn (1984) has found that for high-dispersion LWR and SWP spectra the mean difference between laboratory and observed wavelengths for Pt lines is 2+/-2 km/s for images with standard processing. Systematic errors in the high-dispersion wavelength calibration, which are known to affect archival spectra are discussed in Turnrose, Thompson, and Gass (1984).

VII. Absolute Calibration

Accurate spectrophotometry is dependent on both an accurate calibration of the instrumental sensitivity, linearity effects (discussed above) and the accuracy of the exposure time information.

Correcting Exposure Durations

The exposure durations recorded on the observatory scripts and in the science image header for each spectrum are the nominal exposure durations. The nominal values do not always reflect the actual exposure duration. For short exposures the 0.120 second camera response time (Schiffer 1980; Imhoff 1984), the digitization of the camera exposure times into 0.4096 second increments by the on-board computer, and the uncertainty in the on board computer timing of 0.03 seconds (Bohlin 1985) can cause the actual exposure duration to be appreciably different from the nominal value for short exposures. Exposure times for trailed spectra are not affected by the digitization of the OBC. Exposure times for these observations are given by 20 arcsec divided by the trail rate. The trail rate is indicated on the NASA scripts, and the exposure time based on the nominal aperture length and the specified trail rate is stored in the merged log. Extremely rapid trails can graze or miss the aperture. Spectra obtained with trail rates larger than 20 arcsec/sec result in unreliable fluxes. Some suggested improvements in the trail technique may result in more accurate fluxes (Imhoff 1985b).

One observing techinque for improving the signal to noise in low dispersion large aperture point sources having exposures times too long to effectively trail, and shorter than approximately 100 minutes, is to take multiple spectra offset perpendicular to the dispersion direction in the same image (Wu et al. 1983). Panek (1982a,b) showed that spectra spaced up to 14" apart in the aperture experience a light loss of no more than a few percent. These broadened or "pseudo-trailed" spectra can be reduced using the trailed source extraction scheme. The total effective exposure time is the single point source exposure time multiplied by the number of offset reference points used in the observation so long as no light loss occurs. Reference point information should be contained in the science image header observation information (lines 1-9 of the science image header). The total exposure time is also normally stored in both the merged log and the science image header.

Throughput of the Small Aperture

Small aperture spectra are photometrically unreliable since the aperture transmits 0.5+/-0.25 of the light from a point source (Panek 1982a,b).

The Inverse Sensitivity Function (Low Dispersion)

The IUE inverse sensitivity function is ultimately derived from rocket observations of the bright B3 star Eta UMa. Since Eta UMa is too bright to obtain reliable spectrophotometry in low dispersion, fainter secondary standards were chosen for the bulk of the IUE absolute calibration. Stars were selected for this calibration which had good TD1, OAO-2, and ANS spectrophotometry. The assorted satellite data were corrected onto a common flux scale using the primary ultraviolet standard Eta UMa fluxes (Bohlin et al. 1980, Bohlin and Holm 1984). Fluxes assigned to the secondary standards are given in Bohlin (1985). Once fluxes were available for the secondary standards, IUE spectra of these objects could be reduced and combined as described in Bohlin and Holm (1984) to form the low dispersion inverse sensitivity curve for the appropriate cameras. This calibration is affected by systematic errors, including linearity errors in the IUE observations used in the calibration, the uncertainty in the original Eta UMa fluxes, and other effects which are discussed in Bohlin (1985). Overall, the IUE absolute calibration for low dispersion is accurate to +/-10%. The low dispersion inverse sensitivity curves currently used by IUESIPS are presented in Bohlin and Holm (1981) for SWP and LWR, and in Cassatella and Harris (1982) for the LWP. Thermal variations in camera sensitivities are presented in Sonneborn (1984).

A discussion of mismatches between SWP and LWP spectra processed under the current LWP ITF is given by Harris and Cassatella (1985).

Sensitivity Changes

In the 7 years since the epoch of the original IUE absolute calibration all of the cameras have aged and lost some sensitivity. Camera aging effects are most pronounced for the LWR. Studies by Holm (1985) and Clavel, Gilmozzi, and Prieto (1985) have shown that the largest sensitivity degradation is near 2300 A, but significant effects (0.8%/year up to 3.4%/year) are seen at other wavelengths. Both analyses have assumed a linear dependence upon time and a non-linear wavelength dependence for the camera degradation. Schiffer's (1982) data for thermal sensitivity variations are used in both studies. Holm's data tend to under-compensate for the camera degradation, while Clavel et al.'s method tends to overcompensate slightly (Imhoff 1985d). At the October 1985 3 Agency Meeting, the data of Clavel et al. (1985) have been adopted as the "official" LWR degradation correction data. No correlation between LWR sensitivity changes and the LWR flare have been observed (Sonneborn 1985a). The SWP camera showed a rapid decrease in sensitivity prior to 1979.5, and a very slow degradation thereafter (Sonneborn 1985a). The LWP sensitivity has remained largely stable (Sonneborn 1985a) with maximum degradation of 1% per year from 2350 to 2650 A and no significant changes elsewhere.

High Dispersion Echelle Blaze Function (Ripple)

In high dispersion the absolute calibration is a function of the telescope and spectrograph throughput, the efficiency of the echelle grating, and the camera sensitivity. The telescope, spectrograph, and camera sensitivity all change slowly with wavelength but the echelle grating sensitivity changes rapidly with wavelength across each order due to the strong blaze.

The echelle grating efficiency is a function of both order number and wavelength in each order. When several orders are plotted as a function of wavelength, a rippled or arch-like pattern appears. Early studies of the echelle efficiency (Ahmad 1981) showed that the blaze function, or ripple, has an approximate sinc (x) dependence where $x = m\pi(\lambda - \lambda_c)/\lambda_c$, as predicted by optical theory. Ake (1981, 1982, 1984) showed that a better fit to the ripple could be achieved by assuming that the grating parameter K depended on the order number. Parameterizations with K as a low order function of order number generally describe the ripple for the majority of orders in the majority of spectra. Ake's (1982) analysis of sensitivity variations in high dispersion spectra suggests that K might change as a function of time. SWP and LWR ripple corrections using Ake's results were implemented at GSFC on 27 Aug 1982, and have not been updated since. LWP high dispersion images processed before 1984 December used the LWR ripple constants and were rather inaccurate. LWP high dispersion spectra processed since 1984 December have used the Ake (1984) constants. Some improvement in fits for those spectra of continuum sources where the default ripple correction is not acceptable can be achieved by varying the ripple parameters in a least squares sense until the difference between fluxes in regions of order overlap are minimized (Barker, 1984).

Sensitivity changes in high dispersion have been evaluated for the LWR by Ake (1982) who found that the changes appeared to be a function of position on the camera rather than a function of wavelength. Sonneborn (1985b) has performed a preliminary evaluation of sensitivity changes near 2800 A and has found results similar to Ake (1982) and overall degradation rates which are comparable to the low dispersion results.

High Dispersion Sensitivity Function

The approach used to derive the high dispersion sensitivity function by Cassatella *et al.* (1981, 1983) has been to assume that

$$F_\lambda = N_\lambda C_\lambda S_\lambda^{-1}$$

where N_λ are the high dispersion ripple corrected flux numbers, S_λ^{-1} is the low dispersion inverse sensitivity function, and C_λ is the ratio of the low dispersion response to the high dispersion response at each wavelength. C_λ was derived by obtaining pairs of high and low dispersion spectra of the IUE standards which have been reduced using IUESIPS with default point source processing. The high dispersion spectra are convolved with the low dispersion point spread function and resampled on the low dispersion wavelength scale before the ratio of the low dispersion flux numbers to the high dispersion flux numbers is formed at each wavelength. This is repeated for several observations of each standard star, and for several standard stars. The average response, smoothed if need be to avoid regions of heavy spectral line contamination, is used to generate C_λ for every 25 A. As such the calibration is highly dependent upon the ripple correction and the extraction used. Different calibrations exist for the old software (Cassatella *et al.* 1981) and the new software (Cassatella *et al.* 1983). due to the *large* differences in the background subtraction. Because of the uncertainties in the high dispersion sensitivity calibration, absolutely calibrated spectra are *not* archived with the extracted spectral file data.

Absolutely calibrated spectra are sensitive to both the random errors in the observations of interest, the random errors in the spectra used to derive the calibration data, any inaccuracies in exposure timing and several systematic errors. Linearity errors, spectral and background extraction errors, the accuracy of the ripple correction, and camera degradation can all affect the accuracy of the spectrophotometry.

VII. Evaluation of IUE Spectra

The scientific evaluation of spectra frequently depends upon the intrinsic reproducibility of the instrument, the noise characteristics of the instrument, the presence of detector artifacts and stray signal.

Reproducibility

Reproducibililty studies (Oliversen 1984a) have been made for all three cameras by observing one of the IUE calibration standards HD 60753 (B3). The analysis is for trailed spectra, but similar results hold for point and extended source spectra. Among similar spectra there are rms deviations of 2.52% for SWP, 1.17% for LWR, and 2.17% for LWP. Sonneborn (1984) has studied repeatability in 150 A bands as part of the low dispersion sensitivity monitoring programs. He finds that the 1 sigma uncertainties are 3.3% for SWP, 3.4% for LWR, and 3.5% for LWP in 150 A bands (point source spectra). Bohlin and Coulter (1982) found that for high dispersion spectra processed under the "new" software the reproducibility characteristics are similar to low dispersion data.

Saturated and Extrapolated Fluxes

Data points which have been exposed to DN levels corresponding to saturation (DN=255 in the raw image) or which have DN levels above the highest level in the ITF in use at the time of processing are routinely flagged in the data quality vector which accompanies the extracted spectral data (Turnrose and Thompson 1984). Saturated data points are photometrically unreliable since the spectrum was sufficiently overexposed to exceed the dynamic range of the camera. Extrapolated ITF data points are of uncertain accuracy and should be used with caution. The accuracy of the flags generated by IUESIPS was less reliable in the past due to various differences in processing (see Grady and Imhoff (1985a, this issue)).

Noise

The IUE cameras are subject to several noise sources including readout noise of approximately 10 DN/pixel (Holm 1982) and periodic noise or microphonics. In the SWP camera microphonics cover the entire image with an amplitude of 1-3 DN. The amplitude of the microphonics may be increased by mechanical activity in the spacecraft during a read (Northover 1979). In the LWR microphonics affect a few lines of an image in 85% of images with amplitudes up to 110 DN (Holm 1982). The band of microphonics (or "ping") can be identified by inspecting the photowrite. An assessment of the photometric consequences of the 4-minute heater warmup technique used since 1983 to avoid microphonics is given in Holm and Panek (1982).

The noise seen in any single extracted IUE spectrum is a combination of random and the so-called "fixed pattern" noise. The random contribution may be reduced by averaging spectra. The random contribution is due to photon noise and readout noise. The "fixed pattern" component of the noise is probably due to incomplete rectification of the IUE spectra during the ITF correction. The "fixed pattern" contribution can be reduced by averaging spectra obtained with different reference points or at different times since the "fixed pattern" seems to be stable on timescales on the order of a day or less. The fixed pattern timescale is comparable to the timescales for thermal variations in the cameras. Recent studies of the noise characteristics of high dispersion images (Adelman and Leckrone 1985) have shown that approximately 40% of the noise is random and the rest is "fixed pattern". For further discussion see:

Clarke (1981a) Low Dispersion SWP
West and Shuttleworth (1981)
York and Jura (1982) High dispersion SWP
Adelman and Leckrone (1985)
Joseph (1985)

For a well exposed point-source spectrum with strong continuum and low background levels (continuum DN 160-200, background 20-45) in low dispersion and processed by IUESIPS, signal-to-noise (S/N) ratios of order 10 are typical. Some early calibration studies (Cassatella et al. 1980, Settle et al. 1981) have suggested that S/N of order 25-30 is achievable. In high dispersion LWR and LWP S/N is discussed by Barylak (1984), and SWP by York and Jura (1982). To measure S/N in low dispersion emission line spectra or in featureless parts of the spectrum see the discussion by Ayres (1982). Note that the current IUESIPS extraction of IUE data results in the data being oversampled by about a factor of 5 compared to the resolution element.

Diffuse Backgrounds

Two sources of diffuse background have been identified for IUE spectra. Phosphorescence fogging contributes 6-10 DN/hour/pixel and is dependent upon the number and type of PREPS before the image of interest. Radiation fogging is caused by Cherenkov radiation from electrons in the Van Allen Belts (Coleman et al. 1977), and may be especially severe near perigee (US2 shifts). Spectra obtained under these conditions may have excessively high background levels (check the B value in the comments section of the merged log, or the background DN and FPM value on NASA scripts). The typical radiation fogging levels are worse at solar minimum than maximum (Imhoff 1985c). Note that a high background results in a smaller dynamical range for the spectral signal, and hence a reduced signal-to-noise ratio. Any linearity errors in the background can affect the net fluxes (see Imhoff and Grady 1985 for a dramatic example).

Discrete Backgrounds and Other Defects

The most frequently seen discrete blemishes in an IUE spectrum are the reseaux or registration marks. Since the reseaux are produced by dark spots on the back side of the ultraviolet to visible light converter, no astronomical signal can be present at a reseaux contaminated point. Reseaux are flagged in the IUESIPS extracted spectra data quality file (Turnrose and Thompson 1984).

Interruptions in communications between IUE and the ground computers while an image is being read can result in loss of data for the portion of the image affected. These gaps in the data or telemetry dropouts are visible as horizontal streaks where no signal is present (0 DN in the raw image or large negative fluxes in net or absolutely calibrated net spectra). In offset or pseudo-three dimensional displays of the spatially resolved low-dispersion data dropouts are apparent as troughs crossing the spectrum at an angle.

The IUE cameras are also efficient detectors of charge due either to radioactive disintegrations in the phosphor (Coleman et al. 1977) or to cosmic rays. Cosmic ray tracks (hits) resemble bright spots at normal incidence and look like comets at oblique incidence. Some permanent blemishes are also observed as pseudo-emission features, most notably the 2190 A "feature" seen in LWR low dispersion large aperture spectra. Ponz (1982) discusses other permanent blemishes. Panek (1983) discusses a technique for removing bright spots. Two hot pixels near C IV in high dispersion are noted by Ayres (1982).

The ITF, which is formed from images having short exposure times, does not completely rectify long exposure observations of sources which are faint in the ultraviolet. Analysis of BL Lac object spectra, which are expected to be featureless power-law spectra, has shown that camera artifacts resulting in the distortion of the continuum and smaller resolution-sized artifacts are present (see Hackney, Hackney and Kondo 1982, 1985). At present correction techniques for the camera artifacts are not available.

The IUE cameras suffer from residual image contamination both when a camera has been previously overexposed (Snijders 1983) and when repeated optimal exposures of the same type of spectrum have been made for one or more shifts. Camera preps done with a bright star or earthlight in the large aperture are also known to cause negative residual spectra.

Sky Backgrounds and Scattered Light

Contamination of spectra by light scattered from longer wavelengths is known to affect the spectra of late type (A-K) stars and objects with flux distributions falling sharply with decreasing wavelength. The effects are most pronounced for SWP spectra. Discussions of scattered light in low dispersion SWP spectra are given in Clarke (1981b), Crivellari and Praderie (1982), Basri, Clarke and Haisch (1985) and Imhoff (1985a). The scattering function in Basri et al. (1985) is known to overestimate the effects of scattered light and a corrected version is presented in Basri (1985). The camera response out to 5500 A is given in Holm (1980).

The sky background in the portion of the UV spectrum covered by the IUE cameras is generally negligible except at Lyman alpha. Large aperture spectra with exposure times longer than approximately 15 minutes have appreciable Lyman alpha contamination of the extracted spectrum. Ponz and Penston (1982) give one technique for removal of geocoronal Lyman alpha emission from the extracted spectrum.

Stray light due to a bright star just outside the aperture can also affect the quality of spectra. Schiffer (1982) notes that the amount of stray light in the telescope is proportional to the distance from a bright star (Fscat proportional to d to the (-2.5) power times the stellar flux) where d is the distance in arcseconds (5<d<40). Witt (1982) found similar results in a study of scattered light from Eta UMa.

Apertures

Aperture characteristics are summarized in Faelker (1985). Note that the plate scale quoted in both Faelker (1985) and Holm (1982) has the units inverted. Panek (1982a,b) has the units correct; i.e. 1.5 arcsec/pixel.

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