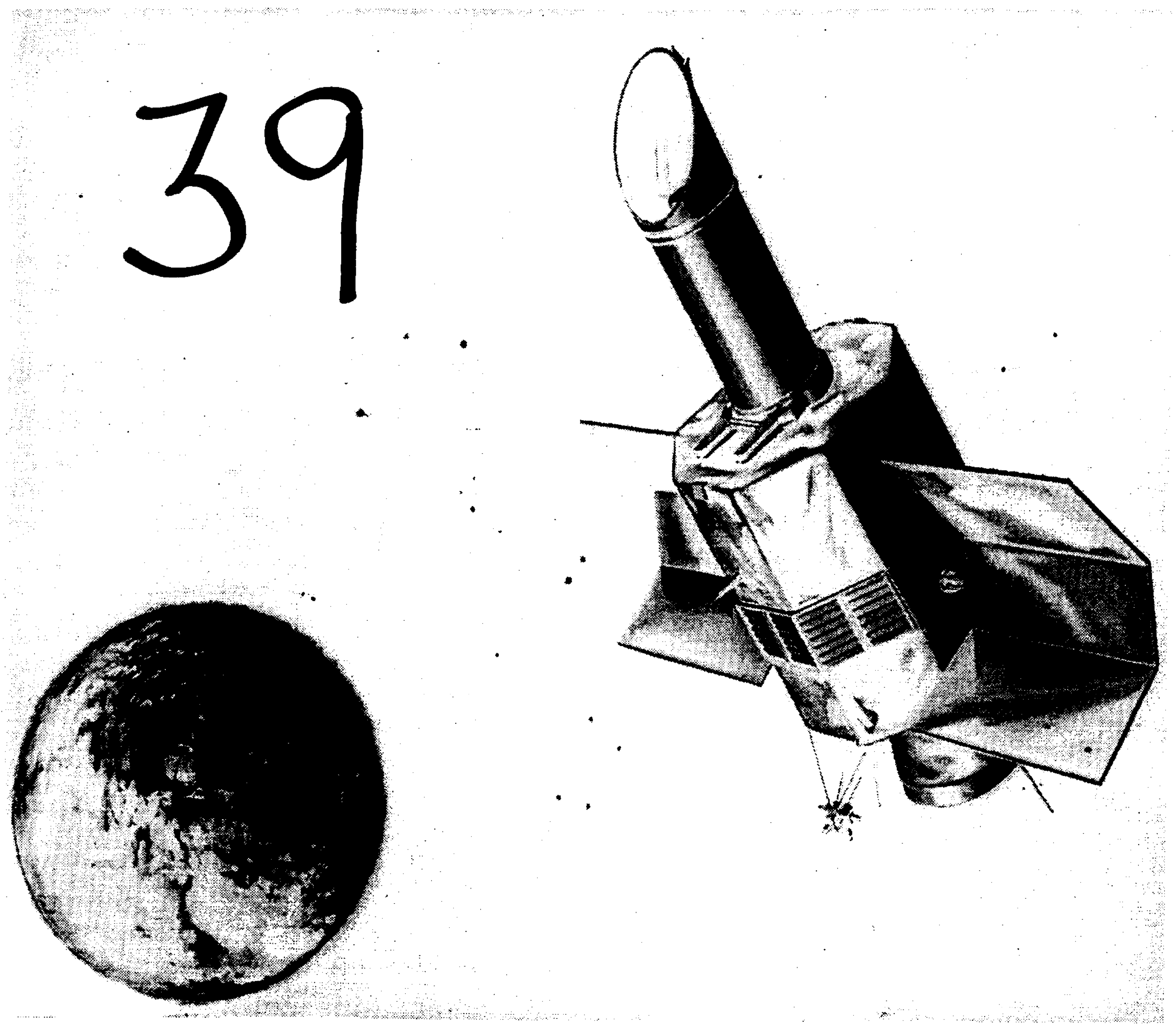
International Ultraviolet Explorer (IUE)

NASA NEWSLETTER



INTERNATIONAL ULTRAVIOLET EXPLORER DATA ANALYSIS GUIDE

Carol A. Grady and Muriel A. Taylor

IUE Observatory
Computer Sciences Corporation
June 9, 1989

Contents

Chapter 1

Introduction

This guide is intended to summarize the information an astronomer needs to analyze International Ultraviolet Explorer (IUE) spectra. The guide is intended both for the new user of IUE archival data and for experienced Guest Observers (GOs). It is necessarily brief, but references are given to other sources of information. It provides a supplement to the IUE Observer's Guide (Sonneborn *et al.* 1987). In addition, the observatory staff welcomes questions from IUE researchers and those interested in becoming IUE researchers.

The IUE satellite has been a prolific source of ultraviolet spectra of essentially all types of astronomical sources, including the earth's upper atmosphere, most of the solar system objects, stars, galactic nebulae and clusters, other galaxies, and active galactic nuclei. The archives contain in almost 70,000 high and low-dispersion spectra. Unlike many optical archives the spectra are available to archival researchers in substantially reduced forms, including the application of most of the calibrations needed to present the data in the form of absolutely calibrated fluxes as a function of wavelength. This is possible largely due to the simplicity and stability of the instrumentation. The IUE is still operational and improvements continue to be made in the processing and calibration. The data as archived reflect the evolution of the image processing system and the understanding of the instrumental characteristics. The quality and suitability of the spectral data for a particular archival problem may be affected by the processing used.

The IUE researcher can get the most out of IUE data by becoming familiar with the instrument, by becoming acquainted with those details of its operation which affect the data quality, understanding the image processing and data reduction used to generate the fully calibrated IUE spectra, and being aware of the limitations of the calibration and image processing which can affect the data quality.

Chapter 2 will summarize those aspects of the scientific instrument which are generally important in understanding the spectral data. Chapter 3 reviews the image processing and calibration. Chapter 4 discusses the evaluation and acquisition of archival data. Chapter 5 covers the basic structure of the Guest Observer format on magnetic tape and the interpretation of the science image header. Chapter 6 briefly describes the

Regional Data Analysis Facilities (RDAFs).

The following references provide valuable detailed information on IUE and its data.

References

SPACECRAFT OPERATIONS:

Boggess, A. *et al.* 1978. *Nature* Vol. 275, 377.

Sonneborn, G., Oliversen, N.A., Imhoff, C.L., Pitts, R.E., and Holm A.V. 1987. "IUE Observer's Guide", *NASA IUE Newsletter* No 32.

IMAGE PROCESSING:

Turnrose, B.E., and Thompson, R.W. 1984. *International Ultraviolet Explorer Image Processing Manual, Version 2.0 (New Software)*, CSC-TM84-6058.

Turnrose, B.E., Harvel, C.A., and Stone, D.F. 1981. *IUE Image Processing Information Manual, Version 1.1 (Old Software)*, CSC-TM81-6268.

Turnrose, B.E., Thompson, R.W., and Gass, J.E. 1984. *NASA IUE Newsletter* No. 25, 40.

Gass, J.E., and Thompson, R.W. 1985. *NASA IUE Newsletter* No. 28, 102.

INSTRUMENT SIGNATURE, CALIBRATION, PITFALLS FOR THE UNWARY:

Grady, C.A., and Imhoff, C.L. 1985. "The IUE Instrument Signature", *NASA IUE Newsletter* No. 28, 86.

Imhoff, C.L., and Grady, C.A. 1985. "Science Fiction with IUE: I.", *NASA IUE Newsletter* No. 26, 66.

Grady, C.A., and Imhoff, C.L. 1985. "Science Fiction with IUE: II.", *NASA IUE Newsletter* No. 28, 140.

Grady, C.A., and Imhoff, C.L. 1986. "Science Fiction with IUE: III.", *NASA IUE Newsletter* No. 29, 46.

IUE TAPE FORMAT:

Turnrose, B.E. and Thompson, R.W. 1984. *IUE Image Processing Information Manual, Version 2.0 (New Software)*, CSC-TM84-6058.

Munoz Peiro, J.R. 1985 *NASA IUE Newsletter* No. 27, 27.

THE RDAFS:

The RDAF Tutorials

The CURDAF guide

IUE DOCUMENTS

We have various IUE documents available to interested astronomers. For your convenience the available documents are listed below. Please note that we generally have a number of copies of the more recent NASA IUE Newsletters available, but only a few copies of some of the older issues in printed form. All back issues of the newsletters are available on microfiche. Most of the NASA IUE symposia are no longer available.

Please feel free to request any of these documents for yourself, your students, or co-workers. In addition, we will be happy to answer questions and seek out any additional information that you need.

Myron Smith
(301) 286-7346
IUE::MSMITH (SPAN)

- -

DATE: ______________________
FROM: ______________________
____
____
____

TO: Dr. Myron Smith
Code 684.9
Goddard Space Flight Center
Greenbelt, MD 20771

Please send me copies of the following IUE documents:

___ IUE Guest Observer's Guide and IUE Data Analysis Guide (NASA IUE Newsletter No. 32)

___ "How to Use IUE Data", from Exploring the Universe with the IUE Satellite

___ IUE Image Processing Manual Version 1.1 (old IUESIPS software)

___ IUE Image Processing Manual Version 2.0 (new IUESIPS software)

___ Time History of IUESIPS Configurations (NASA IUE Newsletter No. 25)

___ IUE RDAF Users' Tutorial Manual

___ IUE RDAF Remote Users' Guide

___ Back issue(s) of recent NASA IUE Newsletter(s) (not all issues available) Numbers: ____________

___ All back issues of NASA IUE Newsletters on microfiche

___ IUE Merged Log on microfiche

___ NASA IUE Symposium: First Two Years of IUE (CP-2171)

___ Other information described below:

IUE Documents Request Form

Chapter 2

A Brief Description of IUE

The IUE spacecraft contains the science instrument, which will be described below, and those systems which are needed to control the instrument, the spacecraft pointing, receipt of commands, and telemetry transmission. The spacecraft is in a geo-synchronous orbit so that continuous communications with it can be maintained from one of its two ground stations. The spacecraft and science instrument contain limited on-board computer facilities and are controlled in real-time from Goddard Space Flight Center (GSFC) or the ESA Villafranca Satellite Tracking Facility (VILSPA) near Madrid. The spacecraft is controlled from GSFC 16 hours a day and from VILSPA the remaining 8. Data read down by a given facility is processed by that facility typically a day or two after the time of observation. Further details on observing with IUE are given in Sonneborn *et al.* (1987). Updated information is normally published in the NASA IUE Newsletters.

The IUE scientific instrument consists of a 45-cm diameter f/15 Cassegrain telescope, offset star tracker, acquisition camera (the FES), and two independent echelle spectrographs for ultraviolet spectroscopy between 1150 Å and 3200 Å. A schematic drawing of the science instrument is given in Figure 1 and a summary of the instrument characteristics is given in Table 1.

2.1 *The FES*

The Fine Error Sensor (FES) is an image dissector which may be used as a camera for field identification or as a star tracker for spacecraft guidance. When used as a camera, the FES can scan a field up to 15 arcminutes square and may then be used by the Guest Observer for target identification. In this mode the FES has 8 arcsecond resolution and can reach to V=13. Fainter targets may be identified by a smaller and deeper FES image which can detect objects down to 15.5 visual magnitude. Images used for target acquisition are not normally archived. If the image of the target is scientifically interesting (as in the case of Comet Halley), or if the image is needed to record the observation history or engineering parameters, the image is archived.

In tracking mode, the FES is used to acquire the target and to guide on a nearby star during an exposure. The FES counts, recorded on the observing scripts, can be used to measure the brightness of the target, if brighter than V=13.5. The conversion of FES counts into V magnitudes, accounting for the non-linear decrease in FES sensitivity as a function of time, color correction terms, and detector dead time, is discussed by Imhoff and Wasatonic (1986) and Sonneborn *et al.* (1987).

2.2 *The Spectrographs*

Each spectrograph has its own apertures, optics, and two cameras (one designated as Prime, the other Redundant). The spectrographs can each be operated in two dispersion modes. In high dispersion the spherical grating shown in Figure 1 is used as a cross-disperser for the echelle grating. The echelle format is shown in Figure 3a which depicts a photographic representation of the spectral format. The IUE echelles are used in orders 60-125, with the orders crowded together at the short-wavelength end of the format. In low dispersion, a flat mirror is rotated into the optical path, blocking the echelle grating. The cross-disperser alone is then used to produce the low-dispersion spectrum. A photographic representation of the low-dispersion format is shown in Figure 3b.

2.3 *The Cameras*

The IUE cameras are SEC Vidicons with proximity focussed ultraviolet-to-visible light converters (UVC). Each spectrograph has two cameras which may be selected by rotation of the camera-select mirror. The cameras designated as Prime are the cameras used if the mirror is not in the optical path. In the long-wavelength spectrograph both cameras have been used for G.O. observations during the IUE mission. The long-wavelength redundant camera (LWR) was the default long-wavelength camera from launch in January 1978 to October 1983. After October 1983 the long-wavelength prime camera (LWP) became the default camera. This occurred because the LWR had developed a discharge in its UVC which contaminated any long exposure, especially in high dispersion. The short-wavelength prime (SWP) has been the default short-wavelength camera since the commissioning period. The short-wavelength redundant camera (SWR) is not operational and is not available for Guest Observer use. A discussion of the camera operation is given in Sonneborn *et al.* (1987). A discussion of camera properties and image processing is given in Turnrose and Thompson (1984).

In the course of the IUE mission, the wavelength-dependent sensitivity of the cameras has gradually changed. The LWR has experienced the largest changes (Clavel *et al.* 1985). Sensitivity changes in the other cameras are discussed in Garhart and Teays (1988). In general the camera characteristics have been remarkably stable.

2.4 *Intricacies of IUE Observations*

Obtaining an IUE spectrum can be divided into several steps:

- maneuvering the spacecraft to the target
- positioning the target in the appropriate aperture
- maintaining spacecraft pointing to keep the position of the target fixed in the aperture
- exposing the camera
- reading the image down and preparing the camera for the next spectrum

The archival researcher should be familiar with the sections in Sonneborn *et al.* (1987) on these topics since the method of observation may have a significant effect upon the quality and accuracy of the resulting spectrum.

2.4.1 *Maneuvering and Target Acquisition*

Maneuver errors and target acquisition uncertainties can affect the centering of the target in the large aperture. A discussion of maneuvering with IUE and the target acquisition procedures is given in Sonneborn *et al.* (1987). Sources acquired using the FES tracker are normally centered in the large aperture to within about 0.5 arcsec. This centering accuracy corresponds to an accuracy of about 1.0 Å in the dispersion direction in low dispersion or 0.03 Å in high dispersion. The absolute wavelength accuracy of small aperture data is somewhat better, but the throughput of the aperture is variable leading to uncertainties in the absolute flux scale.

Sources fainter than approximately V=13.5 cannot be acquired in the normal manner using the FES. These targets have been typically observed as "blind" offsets. The spacecraft is slewed to a nearby SAO star (preferably less than 15 arcminutes from the target), and then slewed to the position of the target. The positioning accuracy of the offset into the large aperture is a function of both the distance of the offset star and the accuracy of the target coordinates. Offsets less than 15 arcminutes typically result in centering uncertainties of $\pm$ 1 to 2 arcseconds. The inaccuracies in the positioning translate into uncertainties in the position of the spectrum on the camera. The uncertainty in position in the dispersion direction translates directly into shifts in the wavelength scale. Miscentering of 3 arcsec along the dispersion direction causes a wavelength shift of about 6.0 Å in low dispersion or 0.2 Å in high dispersion.

2.4.2 *Pointing Control*

During long exposures the satellite's on-board computer (OBC) uses FES star tracking data to maintain pointing stability. Normally this offset guiding will maintain the target centering to within 0.25 arcsec.

Short exposures (usually less than 3 to 5 minutes) do not require a guide star and are typically obtained with the pointing controlled by the gyros. Longer exposures are sometimes obtained with gyro pointing control if no guide star is present. Normally the drift rates are 0.001-0.002 arcsec/sec, which would result in a drift of 0.6 arcsec in 5 minutes. On rare occasions larger drift rates are possible and would result in a smearing of the spectrum. If you are uncertain of the effect on a particular spectrum, please consult the Observatory staff.

2.4.3 *The Exposure*

The exposure can be obtained using one of several techniques.

'Fixed' Pointing

Spectra of 'fixed' targets (either point source or extended objects) are obtained with the spacecraft pointing is held constant. The effective exposure time for bright pointed spectra is dictated by the exposure digitization ('tics') in units of 0.4096 seconds and by the camera response time of 0.12 seconds. See Imhoff (1985) and Crenshaw (1988) for details.

Trailed Spectra

Trailed spectra for a point source are obtained by allowing the spacecraft to drift at a constant rate approximately parallel to the long axis of the aperture. The exposure time is the aperture length (21.4 arcsec for SWP, LWR, and LWP) divided by the trail rate in arcsec/sec.

Multiple Exposure

Pseudo-trailed or broadened spectra of point sources may be obtained with the target positioned at several locations along the large aperture. The resulting multiple exposure is read down as one spectrum. This technique is suitable for fainter targets with point-source exposure times up to 100 minutes. The total exposure time is the sum of all the individual exposures.

Moving Targets

Spectra of moving targets are obtained by slewing the spacecraft to match the movement of the target in the plane of the sky. These spectra are typically processed as normal point-source or extended-source observations, depending upon the nature of the source.

2.4.4 *Determining Large Aperture Orientation*

The orientation of the large apertures of both the short-wavelength and long-wavelength spectrographs is a function of the target coordinates and the time of the year. The procedure for determining the orientation of the large aperture, which is especially important for observations of extended sources, is given in Sonneborn *et al.* (1987).

2.4.5 *Reading the Camera*

The camera exposure and read procedure is described in Sonneborn *et al.* (1987). IUE data are transmitted to the ground in the form of digitized values ranging from 0 to 255 Data Numbers (DN). A typical exposure has contributions from a number of sources, including the electronic pedestal of 20 to 40 DN, a diffuse background ("fogging") due to background particle radiation, the target spectrum, overall camera phosphorescence, sky background at Lyman alpha, discrete radiation events, and in some long exposures residual phosphorescence from previous exposures. Optimal exposures for UV-bright sources typically have a peak DN of 200 to 210 and background exposure levels of 25 to 40 DN. Exposures of fainter sources typically have much higher backgrounds (e.g. a good QSO spectrum may have a peak gross-spectrum exposure level of 200 DN with a background of 70 to 80 DN).

Before the next exposure, the camera must be prepared using a series of tungsten flood-lamp exposures and erase scans. A standard "prep" is used after most exposures. If an overexposure occurs which greater than about 5 times the nominal exposure, an overexposed prep is usually performed to remove the residual image in the target.

References

Boggess, A. *et al.* 1978. *Nature* Vol. 275, 377.

Clavel, J., Gilmozzi, R., and Prieto, A. 1985. *NASA IUE Newsletter* No. 27, 50.

Crenshaw, D. 1988. *NASA IUE Newsletter* No. 35, 51.

Garhart, M.P., and Teays, T.J. 1988. *NASA IUE Newsletter* No. 35, 99.

Imhoff, C.L. 1984. *NASA IUE Newsletter* No. 24, 24.

Imhoff, C.L. 1985. *NASA IUE Newsletter* No. 27, 1.

Imhoff, C.L., and Wasatonic, R. 1985. *NASA IUE Newsletter* No. 29, 45.

Sonneborn, G., Oliversen, N.A., Imhoff, C.L., Pitts, R.E. and Holm, A.V. 1987. "IUE Observer's Guide", *NASA IUE Newsletter* No. 32.

Turnrose, B.E., and Thompson, R.W. 1984. *IUE Image Processing Information Manual, Version 2.0 (New Software)* CSC-TM84-6058.

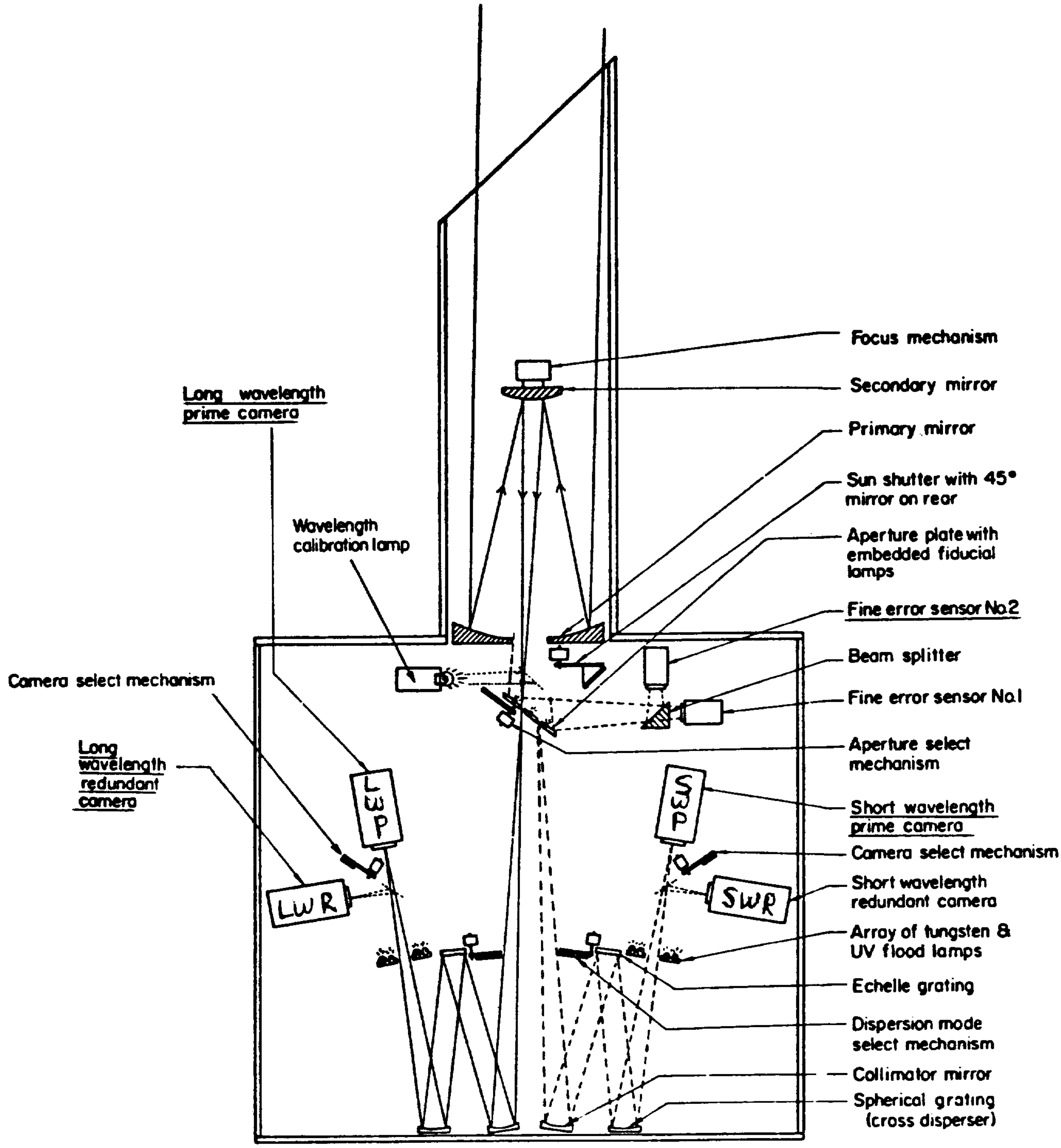


Figure 1: Optical schemetic of the IUE scientific instrument

Table 1: Scientific instrument parameters

Telescope		
Figure	Ritchey Chrétien	
Aperture	45 cm	
Primary Focal Ratio	f/2.8	
Effective Focal Ratio	f/15	
Plate Scale	30.5 arc sec/mm	
Image Quality	3 arc sec	
Acquisition Field	16 arc min diameter	
Spectrographs		
Type	Echelle	
Entrance Apertures	3 arc sec circle 10 × 20 arc sec ellipse	
Detectors	SEC Vidicon Cameras	
High Dispersion	Short λ	Long λ
Range	1165 - 2126 Å	1845 - 3230 Å
Resolving Power	10^4	10^4
Low Dispersion		
Range	1150 - 2000 Å	1825 - 3300 Å
Resolution	6 Å	6 Å

Chapter 3

About IUE Data

The image processing necessary to produce fully calibrated spectra is quite complex and has been improved considerably since the launch of IUE. The data in the archives have typically been processed using the version of the image processing system in use at the appropriate ground station close to the time of observation. Some spectra have been reprocessed; for these data the date of processing must be used to characterize the particular version of the image processing system applicable to the data. If spectra from very different epochs are being analyzed for a research program, the investigator must keep in mind that the data will generally have been treated differently and may be subject to changes or errors in the image processing algorithms, calibrations, and instrumental characteristics.

The IUE Spectral Image Processing System (IUESIPS) is frequently referred to as the "old" software and the "new" software, reflecting large changes made in the processing in 1981-1982. Low-dispersion data processed at GSFC (VILSPA) before 4 Nov 1981 (10 March 1981) was processed with the "old" software. SWP and LWR h igh-dispersion data processed at GSFC (VILSPA) before 10 November 1981 (11 March 1982) were processed with the "old" software. LWP Hi gh-dispersion data processed at GSFC (VILSPA) before 7 January 1982 (11 March 1982) were processed with the "old" software. The description of this version of the processing software is given in Turnrose, Harvel,and Stone 1981. Images processed after these dates used the "new" software. The description of the later software is given in Turnrose and Thompson 1984. Changes made to low-dispersion spatially-resolved data are described in Munoz Peiro (1985).

For an overview of the calibration of the IUE, the corrections applied to spectral data by IUESIPS, and other data characteristics see "The IUE Instrument Signature" by Grady and Imhoff (1985a). Some of the hazards of neglecting the limitations of the IUE calibration, image processing, and observing procedures in the analysis of IUE spectra are discussed in the series of articles "Science Fiction with IUE" by Imhoff and Grady (1985) and Grady and Imhoff (1985b, 1986a).

3.1 *Overview of Image Processing*

The IUE detectors are SEC Vidicon cameras, with ultraviolet-to-visual 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 Manuals for details.

3.1.1 *Geometric Correction*

Geometric correction of IUE images is required because the "pixels" which are read out are read-beam locations on the camera target. Since the pointing of the read-out beam varies with temperature and local exposure levels, the raw data are mapped to a geometrically-correct domain using a reseau grid on the camera faceplate before the other corrections are applied. The way this mapping is applied to the data is fundamentally different for images processed with the "old" and "new" software. In the "old" software, the raw data were explicitly geometrically corrected. In the "new" software, the calibration data are mapped onto the raw image in a geometrically correct manner.

3.1.2 *The Intensity Transfer Function (ITF)*

The data must 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 various exposure levels. The ITF is normally constructed by averaging several (usually 4 or 5 images) individual flat-field images for each of 11 or 12 discrete exposure levels. The linearization function is then derived for each pixel in the geometrically-corrected image, thus correcting the raw signal in DNs to Flux Numbers (FNs). 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 little compensation for pixel-to-pixel sensitivity variations is made. Grady and Imhoff (1985a) summarize studies of departures from perfect linearization by the ITF and the signal-to-noise characteristics of the IUE cameras. Camera artifacts, residual images, and other sources of data contamination are also covered by Grady and Imhoff (1985a).

3.1.3 *Wavelength Calibration*

The wavelength calibration of IUE spectra is derived from the positions of platinum emission lines in the geometrically-corrected wavelength calibration image. The coefficients of the analytic relation between order number, 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.

3.1.4 *Spectral Extraction*

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. Normally the extraction is registered precisely with the spectrum, but it may be offset either accidentally or purposely 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 old software, the slit was $\sqrt{2}$ pixels wide.) For large aperture observations the size of the extraction slit in the spatial dimension is controlled by the extraction method, such as point source, trailed, or extended source extraction as 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 omit the pair-wise averaging and have spatially resolved spectral files of 110 lines.

Gross slit-integrated spectra are formed for point-source spectra by adding 9 (before October 1985) or 18 (October 1985 to present) lines of the spatially resolved data. Gross slit-integrated spectra for extended sources are formed by adding 15 (before October 1985) or 30 (October 1985 to present) lines of the spatially resolved data. Background spectra are produced by summing the unflagged data points in 5 (before October 1985) or 10 (October 1985 to present) adjacent lines on each side of the gross spectrum, normalizing the summed background to the size of the gross spectrum extraction width, and then filtering the normalized background. Point-source backgrounds are offset from the gross spectrum by 8 lines (before October 1985) or 16 lines (October 1985 to present) corresponding to $8\sqrt{2}$ pixels in the spatial direction, while extended source backgrounds are offset by 11 lines (October 1985 to present) or 22 lines (October 1985 to present) corresponding to $11\sqrt{2}$ pixels. Flagged data are excluded from the averaging in forming the background but are included in the gross spectrum. 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 percent 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 adjacent orders, and averaging the inter-order spectra on each side of the order of interest prior to filtering.

3.1.5 *Absolute Calibration*

The absolute calibration, or conversion of linearized FN to flux units of ergs cm^{-2} s^{-1} Å^{-1}, 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 percent), the signal-to-noise characteristics of the calibration and source 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. Changes in the image processing over the IUE mission which affect the data quality are tabulated in Turnrose, Thompson, and Gass (1984) and Gass and Thompson (1985). Limitations of the IUE calibration affecting the data quality are summarized in Grady and Imhoff (1985a) and the references contained therein.

3.2 *Major Changes in the Image Processing During the IUE Mission*

The following list summerizes those changes to the IUESIPS reduction procedures which are most likely to be pertinent to decisions as to whether archive data require reprocessing. As such, it provides guidelines only, and users are urged to consult the references listed at the end of the summary for more quantitative detailed discussions of the effects of the various changes listed.

LOW DISPERSION

CORRECT SWP ITF ERROR

GSFC 7 July 1979 and VILSPA 7 Aug 1979

- removed photometric error at 20 percent exposure level of ITF

IMPLEMENTATION OF "NEW SOFTWARE"

GSFC 4 Nov 1980 and VILSPA 10 Mar 1981

- doubled spectral extraction frequency, halved slit width
- geometric resampling handled differently
- increased apparent spectral resolution
- increased point-to-point noise (approx. factor of $\sqrt{2}$)
- better background handling
- basic photometry unchanged

EXTENDED LINE-BY-LINE FILE

GSFC/VILSPA 1 Oct 1985

- increased spatial resolution perpendicular to dispersion

NEW LWP CALIBRATION

GSFC/VILSPA, 22 Dec 1987

- Improved fluxes and signal-to-noise

HIGH DISPERSION

TIME/TEMPERATURE CORRECTED GEOMETRIC WAVELENGTH CALIBRATIONS

GSFC 19 May 1981 and VILSPA 11 Mar 1982

- reduced residual internal wavelength errors (1σ less than 2-3 km/sec)

IMPROVED SPECTRAL REGISTRATION AT CROWDED ORDERS

GSFC 28 Aug 1981 and VILSPA 11 Mar 1982

- better background placement, hence better net fluxes

IMPLEMENTATION OF "NEW" SOFTWARE

GSFC 10 Nov 1981 LWR-SWP, GSFC 7 Jan 1982 LWP, and VILSPA 11 Mar 1982

- doubled spectral extraction frequency, halved slit width
- explicit geometric resampling eliminated
- increased apparent spectral resolution
- increased (but more realistic) point-to-point noise (approx. factor of 2 unfiltered, approx. $\sqrt{2}$ when filtered)
- further improved background placement, and better handling
- better photometry (increased net fluxes at short wavelengths, due to lower background; better stability)

NEW LWP CALIBRATION

GSFC/VILSPA, 22 Dec 1987

- Improved fluxes and signal-to-noise

References

Bohlin, R.C., Lindler, D.J. and Turnrose, B.E. 1981. "Results of Basic Improvements to the Extraction of Spectra from IUE Low Dispersion Images", *NASA IUE Newsletter* No. 12, 9.

Bohlin, R.C. and Turnrose, B.E. 1982. "Implementation of Basic Improvements to Extraction of High Dispersion Spectra", *NASA IUE Newsletter* No. 18, 29.

Bohlin, R.C., and Coulter, B.T. 1982. "Photometric Stability in High Dispersion", *NASA IUE Newsletter* No. 19, 48.

Cassatella, A., Holm, A.V., Ponz, D., and Schiffer F.H. 1980. "A Correction Algorithm for Low Dispersion SWP Spectra", *NASA IUE Newsletter* No. 8, 1.

Gass, J.E., and Thompson, R.W. 1985. "Techniques of Reduction of IUE Data: Time History of IUESIPS Configuration-1984 Supplement", *NASA IUE Newsletter* No. 28, 102.

Grady, C.A. 1982. "Problems and Programming for Analysis of IUE High Resolution Data for Variability", *NASA CP-2171*, 805.

Grady, C.A. and Imhoff, C.L. 1985a. "The IUE Instrument Signature", *NASA IUE Newsletter* No. 28, 101.

Grady, C.A. and Imhoff, C.L. 1985b. "Science Fiction with IUE. II", *NASA IUE Newsletter* No. 28, 140.

Grady, C.A. and Imhoff, C.L. 1986. "Science Fiction with IUE. III", *NASA IUE Newsletter* No. 29, 46.

Holm, A.V. and Shiffer, F.H. 1980. "A Comparative Study of Five SWP Low-Dispersion Correction Algorithms", *NASA IUE Newsletter* No. 8, 45.

Imhoff, C.L. and Grady, C.A. 1985. "Science Fiction with IUE. I", *NASA IUE Newsletter* No. 26, 66.

Munoz Peiro, J.R. 1985. "Generation of the New Extended Line-By-Line Spectrum (ELBL)", *NASA IUE Newsletter* No. 27, 27.

Thompson, R.W., Turnrose, B.E. and Bohlin, R.C. 1982. "The Parameterization of the Motion of the IUE Reseau Grids and Spectral Formats as a Function of Time and Temperature", *Astron. Astrophys.* Vol. 107, 11.

Turnrose, B.E., Bohlin, R.C., and Lindler, D.J. 1981. "Implementation of New Low Dispersion Software: Summary of Output Format Changes", *NASA IUE Newsletter* No. 17, 2.

Turnrose, B.E. and Harvel, C.A. 1982. "Techniques of Reduction of IUE Data: Time History of IUESIPS Configurations", *NASA IUE Newsletter* No. 16, 1.

Turnrose, B.E., Thompson, R.W., and Bohlin, R.C. 1982. "Implementation of New High Dispersion Software: Summary of Output Format Changes", *NASA IUE Newsletter* No. 18, 21.

Turnrose, B.E., Harvel, C.A., and Stone, D.F. 1981. *IUE Image Processing Information Manual, Version 1.1 (Old Software)*, CSC-TM81-6268.

Turnrose, B.E., and Thompson, R.W., 1984. *IUE Image Processing Information Manual, Version 2.0 (New Software)*, CSC-TM84-6058.

Turnrose, B.E., Thompson, R.W., and Gass, J.E. 1984. "Techniques of Reduction of IUE Data: Time History of IUESIPS Configurations", *NASA IUE Newsletter* No. 25, 40.

Chapter 4

Selecting and Ordering IUE Archival Data

The first step in analyzing IUE archival data is deciding whether observations which are applicable to your project exist and identifying those spectra which are suitable for further analysis. The basic reference for IUE observations is the IUE Merged Observing Log.

4.1 *The Merged Observing Log*

The Merged Log (so-called because the observation logs from GSFC and VILSPA have been combined) contains a one-line description for each exposure. The Merged Log is distributed with the NASA IUE newsletters approximately once a year in microfiche, is mailed in microfiche to all astronomers on the proposal mailing list as part of the proposal preparation instructions, and is available on-line at both IUE Regional Data Analysis Facilities (RDAF). The IUE Observatory also has the same information printed in large format, several copies of which are available for use at the Observatory. The log has three parts, a sort in order of increasing Right Ascension, a sort by date of observation, and by Object Class (see table below for the Object Classes).

The microfiche and printed forms of the Merged Log contain introductory information on the FES calibration, object classification codes, exposure level coding information, and a list of the approved NASA, ESA, and SERC observing programs with principal investigator and program title in addition to the actual observation log. Much of the information in the merged log is specified by the individual observers and may not be consistent from observer to observer. Such entries are noted below by an asterix (*).

- Object identification *
- Program identification code. A five character alphanumeric code identifying the observing program.

- Target right ascension and declination in 1950 coordinates. *
- Magnitude: For GSFC observations this quantity is specified by the observer. VILSPA observations obtained since January 1983 have magnitudes calculated from the FES counts and FES tracking mode.
- B-V or E(B-V) *
- Spectral type and luminosity class *
- Object Class. A code to indicate general classes of astronomical objects (e.g. planets, G dwarfs, and BL Lac objects). *
- FES mode and counts (see section 2)
- Image sequence number
- Spectrograph dispersion (high or low)
- Target aperture (large or small)
- Large aperture status (open or closed)
- Exposure duration
- Observation date and time
- Station ID (VILSPA or GSFC)
- Image processing date
- Comments. These typically include exposure level information provided by the telescope operator, problems with the image (e.g. microphonics contamination), use of multiple source positions in the large aperture, and other information. NASA observations have the exposure level information specified in the form of Data Numbers (DN) at emission lines (E), the continuum (C), and in the background (B). DN range from 0 to 255 with an optimal exposure having E or C between 200 and 210. Overexposed spectra are usually designated as n times overexposed (e.g. 5x).

  VILSPA exposure levels are classified using a three digit code. Digit 1 is the exposure level of the continuum. Digit 2 is the exposure level of emission lines. Digit 3 is the exposure level of the background. The continuum and emission lines are classified:

0 = not applicable
1 = no spectrum visible

2 = faint spectrum: max DN $<$ 20 above local background
3 = underexposed: max DN $<$ 100 above local background
4 = weak: 100 $<$ max DN $<$ 150 above local background
5 = good: no saturation, max DN $>$ 150 above local background
6 = a few pixels saturated
7 = saturated for less than half of the spectrum
8 = mostly saturated, but some parts usable
9 = completely saturated

The background is classified:

0 = DN $<$ 20	6 = 71 $<$ DN $<$ 80
1 = 21 $<$ DN $<$ 30	7 = 81 $<$ DN $<$ 90
2 = 31 $<$ DN $<$ 40	8 = 91 $<$ DN $<$ 100
3 = 41 $<$ DN $<$ 50	9 = DN $>$ 101
4 = 51 $<$ DN $<$ 60	x = saturated
5 = 61 $<$ DN $<$ 70	

OBJECT ID	PROG ID	TARGET RA HR MN SEC	TARGET DEC DEG MN SC	VIS MAG	B-V OR E(B-V)	SPEC TYPE	OB CL	FES MODE & COUNTS	IMAGE SEQUENCE NUMBER	DAL	EXPOSE TIME MN SC	OBSERVATION DATE YRDAY HR MN	STA	PROC DATE YRDAY	OBSERVER'S COMMENTS
HR 2990	CSBKN	07 42 15.6	+28 08 55	1.1	0.01	KO III	47	FU 7492	SWP 7432	LLO	099 59	79353 00 45	G	79353	E=74X,C=4X,B=47
HR 219	CSBKN	00 46 03.4	+57 33 03	3.4	0.58	GO V	44	FU 2700	SWP 7433	LLO	021 59	79353 03 23	G	79353	C=3X,B=27
HR 219	CSBKN	00 46 03.4	+57 33 03	3.4	0.58	GO V	44	FU 2531	LWR 6428	HLO	025 59	79353 03 52	G	79353	E=213,C=2-3X,B=50
HR 219	CSBKN	00 46 03.4	+57 33 03	3.4	0.58	GO V	44	FU 1872	SWP 7434	LLO	120 00	79353 04 24	G	79353	E=24X,C=20X,B=60
HR 7957	CSBKN	20 44 16.5	+61 38 39	3.4	0.02	KO IV	46	FU 1004	SWP 7435	LLO	029 59	79353 07 03	G	79353	E=58,C=60,B=38
HR 7957	CSBKN	20 44 16.5	+61 38 39	3.4	0.02	KO IV	46	FU 1000	LWR 6429	HLO	025 00	79353 07 39	G	79353	E=201,C=25%,B=32
HR 7957	CSBKN	20 44 16.5	+61 38 39	3.4	0.02	KO IV	46	FU 991	SWP 7436	LLO	098 00	79353 08 12	G	79353	E=3X,C=130,B=65
JUPITER	UZ180	10 47 05.0	+08 53 00	-02.0			03	FU 1514	SWP 7437	LSO	020 00	79353 11 22	V	79353	401 CENTRE
JUPITER	UZ180	10 47 05.0	+08 53 00	-02.0			03		LWR 6430	LSC	090 00	79353 12 02	V	79353	804 SOUTH POLE
JUPITER	UZ180	10 47 05.0	+08 53 00	-02.0			03		SWP 7438	LLO	002 15	79353 13 52	V	79353	402
SATURN	UZ180	11 49 45.0	+03 24 00	+01.3			03	FU 260	SWP 7439	LLO	020 00	79353 15 43	V	79353	802
LHA332	VILSP	11 10 51.0	-76 28 00	+10.9			58	FO 109	LWR 6431	LLO	013 00	79353 17 35	V	79353	302
M2-58-22	QSBAB	23 02 07.2	-08 57 19	13.9	0.0	O	84	SO 40	SWP 7440	LLO	195 00	79353 19 04	G	79354	E=234,C=120,B=46
M2-58-22	QSBAB	23 02 07.1	-08 57 19	13.9	0.0	O	84	SO 40	LWR 6432	LLO	180 00	79353 22 36	G	79354	E=195,C=170,B=55
		00 00 00.0	+00 00 00	+99.9			99		LWP 1195		000 00	79354 00 00	V	00000	SAFETY READ
		00 00 00.0	+00 00 00	+99.9			99		LWP 1196		000 00	79354 00 00	V	00000	NULL
		00 00 00.0	+00 00 00	+99.9			99		LWP 1198		000 00	79354 00 00	V	00000	NULL
JUPSAT-3	SSBDM	.		5.00	0.0	G	04	FO19645	LWR 6433	LLO	001 29	79354 02 42	G	79354	C=245,B=23
MAGSFERE	SSBDM	.		6.0	0.82	G5 V	04		SWP 7441	LLO	280 00	79354 02 46	GR	79354	B=255
JUPSAT-3	SSBDM	.		5.00	0.0	G	04	FO19401	LWR 6434	LLO	004 29	79354 03 19	G	79354	C=3X,B=26
UPSAT-4	SSBDM	.		6.0	0.82	G5 V	04	FO 6549	LWR 6435	LLO	004 44	79354 04 05	G	79354	C=225,B=21
UPSAT-4	SSBDM	.		6.0	0.82	G5 V	04	FO 7291	LWR 6436	LLO	014 59	79354 04 42	G	79354	C=3X,B=27
UPSAT-2	SSBDM	.		6.0	0.82	G5 V	04	FO13632	LWR 6437	LLO	004 30	79354 05 49	G	79354	C=245,B=23
UPSAT-2	SSBDM	.		6.0	0.82	G5 V	04	FO13454	LWR 6438	LLO	014 59	79354 06 34	G	79354	C=3X,B=28
JUPSAT-3	SSBDM	.		6.0	0.82	G5 V	04	FO20541	LWR 6439	LLO	001 29	79354 07 33	G	79354	C=235,B=28
UPSAT-2	SSBDM	.		6.0	0.82	G5 V	04	FO13209	LWR 6440	LLO	004 00	79354 08 10	G	79354	C=264,B=25
UPSAT-1	SSBDM	.		6.0	0.82	G5 V	04	FO17126	LWR 6441	LLO	018 59	79354 08 45	G	79354	C=250,B=32
HD 52973	UKFIL	07 01 09.0	+20 39 00	+03.7			53	FU 509	SWP 7442	LLO	090 00	79354 10 27	V	79354	301 LONG PARTICLE TR
HD 52973	UKCAL	07 01 09.0	+20 39 00	+03.7			53	FU 527	LWP 1197	LLO	000 30	79354 12 24	V	79354	501
HD 52973	UKCAL	07 01 09.0	+20 39 00	+03.7			53	FU 527	LWR 6442	LLO	000 30	79354 13 02	V	79354	503 703
HD 52973	UKCAL	07 01 09.0	+20 39 00	+03.7			53	FU 527	LWR 6442	LSO	010 00	79354 13 09	V	79354	503 703
HD 52973	UKFIL	07 01 09.0	+20 39 00	+03.7			53	FU 533	SWP 7443	LLO	160 00	79354 13 24	V	79354	503 LONG PARTICLE TR
HD 52973	UKFIL	07 01 09.0	+20 39 00	+03.7			53	FU 544	LWR 6443	HLO	045 00	79354 17 01	V	79354	533 SOME TELEM DROPO
Q 351+026	QSBAD	03 51 32.9	+02 40 41	16		QS	85		SWP 7444	LLO	356 00	79354 19 39	G	79355	B=73
MARS	SMBAL	.		0.4		G	03	FU18612	LWR 6444	LSO	000 04	79355 02 58	G	79355	C=120,B=25
MARS	SMBAL	.		0.4		G	03	FU	LWR 6444	LLO	000 01	79355 03 01	G	79355	C=170,B=25
MARS	SMBAL	.		0.4		G	03	FU19365	LWR 6445	LSC	000 15	79355 03 37	G	79355	C=1.5X,B=25
MARS	SMBAL	.		0.4		G	03	FU	LWR 6445	LLO	000 03	79355 03 41	G	79355	C=3X,B=25
UPSAT-1	SSBDM	.		6.0	0.82	G5 V	04	FO18440	LWR 6446	LLO	017 59	79355 05 01	G	79355	C=205,B=29
MAGSFERE	SSBDM	.		6.0	0.82	G5 V	04		SWP 7445	LSO	105 00	79355 05 28	G	79355	C=255,B=190

Portion of the Merged Log Printout

GLOSSARY OF OBJECT CLASSIFICATIONS

00 SUN
01 EARTH
02 MOON
03 PLANET
04 PLANETARY SATELLITE
05 MINOR PLANET
06 COMET
07 INTERPLANETARY MEDIUM
08 GIANT RED SPOT
09
10 W C
11 WN
12 MAIN SEQUENCE O
13 SUPERGIANT O
14 OE
15 OF
16 SD O
17 WD O
18
19 OTHER STRONG SOURCES
20 B0-B2 V-IV
21 B3-B5 V-IV
22 B6-B9.5 V-IV
23 B0-B2 III-I
24 B3-B5 III-I
25 B6-B9.5 III-I
26 BE
27 BP
28 SDB
29 WDB
30 A0-A3 V-IV
31 A4-A9 V-IV
32 A0-A3 III-I
33 A4-A9 III-I
34 AE
35 AM
36 AP
37 WDA
38 HORIZONTAL BRANCH STARS
39 COMPOSITE SPECTRAL TYPE
40 F0-F2
41 F3-F9
42 FP
43 LATE-TYPE DEGENERATES
44 G V-IV
45 G III-I
46 K V-IV
47 K III-I
48 M V-IV
49 M III-I
50 R, N, OR S TYPES
51 LONG PERIOD VARIABLE STARS
52 IRREGULAR VARIABLES
53 REGULAR VARIABLES
54 DWARF NOVAE
55 CLASSICAL NOVAE
56 SUPERNOVAE
57 SYMBIOTIC STARS
58 T TAURI
59 X-RAY
60 SHELL STAR
61 ETA CARINAE
62 PULSAR
63 NOVA-LIKE
64 OTHER
65 MISIDENTIFIED TARGETS
66 INTERACTING BINARIES
67
68
69 HERBIG-HARO OBJECTS
70 PLANETARY NEBULA + CENTRAL STAR
71 PLANETARY NEBULA - CENTRAL STAR
72 H II REGION
73 REFLECTION NEBULA
74 DARK CLOUD (ABSORPTION SPECTRUM)
75 SUPERNOVA REMNANT
76 RING NEBULA (SHOCK IONIZED)
77
78
79
80 SPIRAL GALAXY
81 ELLIPTICAL GALAXY
82 IRREGULAR GALAXY
83 GLOBULAR CLUSTER
84 SEYFERT GALAXY
85 QUASAR
86 RADIO GALAXY
87 BL LACERTAE OBJECT
88 EMISSION-LINE GALAXY (NON-SEYFERT)
89
90 INTERGALACTIC MEDIUM
91
92
93
94
95
96
97
98 WAVELENGTH CALIBRATION LAMP
99 NULLS AND FLAT FIELDS

4.2 *Observing Scripts*

All observations made at GSFC have an accompanying observation record or "script" which contains the information specified by the Guest Observer for the observation and subsequent data processing. The telescope operator (T.O.) fills in information in the lower portion of the script below the dotted line as the observation is obtained. The following entries appear on the current NASA scripts. Earlier scripts differ somewhat in format and completeness of information provided. More complete information on the observation scripts can be found in Sonneborn *et al.* (1987).

The back of the script contains telescope focus, radiation, and THDA information noted at intervals during long exposures. It also contains the T.O.'s worksheet for telescope-pointing information, which is not generally of interest to those working with archival data.

The VILSPA observation log contains essentially the same information that is subsequently incorporated into the IUE Merged Log.

4.3 *How to Determine Data Quality*

The quality of a particular spectrum can be determined from script and merged log annotations, by inspecting the photowrites, and by inspecting the IUE Low Dispersion Microfiche Plots which are available at the IUE Observatory, the CURDAF, and several major institutions.

The exposure information contained in the scripts and Merged Log can give the archival researcher a crude measure of the signal-to-noise in a particular spectrum. The continuum and emission-line DN measurements at GSFC and the VILSPA coded exposure comments apply to the highest sensitivity portions of the spectrum. For the LWR and LWP this implies measurements in the vicinity of 2800 Å. For SWP spectra the measurement is typically in the vicinity of 1800 Å. If the source flux levels are a strong function of wavelength, as is not uncommon, these exposure measures will not be representative of the entire spectrum. For example, consider an SWP spectrum of an A3 star. The flux from such an object falls steeply shortward of 1600 Å. A spectrum may be overexposed near 1800 Å, and may register only a weak continuum shortward of 1400 Å. The photowrites are especially useful in determining the relative exposure levels of different wavelength regions in the same spectrum.

4.4 *Microfiche Plots of Low Dispersion Spectra*

The IUE Observatory, the CURDAF, and a few other observatories have copies of the IUE Low Dispersion Microfiche Plots of spectra obtained up to early 1985 produced by Rutherford Appleton Laboratories (SERC). These plots are suitable for assessing expo-

Information on this form will be available to all IUE Guest Observers

OBSERVER Verne Smith
OBJECT HD 49331 (HR 2508)
RA (1950) 06^h 45^m 13^s.8
DEC (1950) −08° 56′ 33″

PROGRAM ID HCHDL
Date 28 Dec. 1985
Target Serial No. 3

m_v 5.07 Sp. T. M2IIS
E(B-V) ____ Class No. 49 (B-V) +1.80

Camera LWP / LWR (SWP)
PREP (Standard) ✓ Overexposed Other
Dispersion Mode High (Low) ✓
Large Aperture Close (Open) ✓
Object Aperture Small (Large) ✓
EXPO Time 130 min ____ sec Trailed Multiple

READ (Normal) Ping Avoidance Other
Over-exposure ___ X expected
Remarks:

PROCESSING SPECIFICATIONS
*** NO DEFAULTS ***

Processing Type:
Point Source X
Extended (lo disp) ____
Trailed (lo disp) ____
Full Aperture (hi disp) ____

Process Both Apertures ____

Registration:
Automatic Shift
Manual Shift X
Do Not Shift ____

CalComp Plots
Plots Desired: Yes X No ____
Scale SWP w/o Ly alpha ____

Remarks for IPC/DMC:

RA/TO Crenshaw / Garhart Observatory Record Number 35473
FES Counts Out 20210 In 71 (Overlap Fast) Underlap Slow

Tracking Mode FES (FES + GYRO) GYRO X −910 Y −789 CT 127 s/o
S/C ROLL 188, 18, 30.3

Focus −2.16 Radiation 0.79 Beta 32, 34, 37.2 FSS Roll 0, 0, 7.2

EXPO Start UT Day 362 Hr 06 Min 38 Sec 27 THDA in Expo 12.8

READ Start UT Day 362 Hr 08 Min 49 LWR extended heater warmup/ LWP bad scan starts ____

Archive Tape #6582 IMAGE SEQUENCE No. SWP 27403

EXPOSURE LEVELS
Emission ____ DN, or ____ X OVER
Continuum 115 DN, or ____ X OVER
Background 43 DN, or ____ X OVER
Noise 2 DN, Y ____

Comments:
Read in convolved data

Figure 2a: Sample point source low-dispersion spectrum script

Image Seq. No. SWP 27403 **Program ID** ~~HEO~~ HCHDL

Target Name HD 49331 **Day** 1985/362

(×10⁻³)

GMT	FOCUS	FPM	THDA	ABG-P	ABG-Y	$\dot{P}$	$\dot{Y}$	$\dot{R}$	TMP2	COUNTS	
06:40	-2.16	0.79	12.8	-0.30	-0.15	—	—	—	-1.7	127	S/O
07:00	-1.82	0.57	12.8	1.43	1.43	1.44	1.32	—	-1.7	130	
07:30	-1.91	0.08	12.8/13.2	3.49	2.31	1.14	0.49	—	-1.7	129	
08:00	-0.93	0.08	13.2	5.61	3.34	1.18	0.57	—	-1.3	129	
08:01	—	—	—	0	0	0.001	0.0005	trim			
08:30	-0.95	0.08	12.8/13.2	0.89	-0.05	—	—	—	-1.3	128	

Figure 2b: Back of sample point source low-dispersion spectrum script

Contents of NASA Scripts

Number	Quantity	Description
1	Observer	Name of Guest Observer (G.O.), frequently not the Principal Investigator.
2	Target Name	Target name†.
3	RA and Dec	Right Ascension and Declination in 1950 coordinates†.
4	Mv	Magnitude in the V band†.
5	Spectral Type	Spectral Type†.
6	E(B-V) or B-V	Color excess or color†.
7	Object Class	Type of object in a standardized numerical code†.
8	Camera	The camera used for the observation: LWP, LWR, SWP, or SWR†.
9	Prep	Standard or overexposed†
10	Dispersion	High or low†
11	Large Aperture	The large-aperture shutter may be open or closed†.
12	Object Aperture	Large, small or both apertures may be used†
13	Exposure Time	The nominal value, not including digitization or camera response time†.
14	Trailed/Multiple	Indicates if trailed or multiple exposures were obtained†.
15	Read	Usually normal for SWP and LWP. Some LWR spectra were read with a 4 minute heater warmup in order to reduce the probability of microphonic noise†.

† Specified by the Guest Observer

Contents of NASA Scripts con't.

Number	Quantity	Description
16	Overexposure	Filled in if the G.O. is planning a deliberate overexposure of some portion of the spectrum†.
17	Remarks	Requested trail rates, offset stars or other G.O. comments†.
18	Program	The G.O. program the data were archived under†.
19	Date	Date of observation (may not always be U.T.)†.
20	Target	Number assigned to target in G.O.'s proposal†.
21	Processing Type	Specifies how the spectral extraction will be handled: point source, extended, or trailed for low dispersion, point source or full aperture for high dispersion†.
22	Process Both Apertures	Used if both small- and large-aperture spectra are to be processed†.
23	Registration	Automatic, manual, or no shift applied using standard dispersion relations†.
24	CalComp Plots	Request plots to be sent to the G.O†.
25	Remarks	Notes about special processing, science image header or documentation errors, and other notations.
26	RA/TO	Resident Astronomer and Telescope Operator on duty.
27	FES counts	Average FES counts on object at the Reference Point before the start of the exposure (none listed if blind offset).
28	FES mode	FES mode for target counts.
29	Tracking mode	FES, gyro, or both (under the 2 gyro system since August 1985).
30	X,Y	Location of guide star in FES units.

† Specified by the Guest Observer

Contents of NASA Scripts con't.

Number	Quantity	Description
31	CT	FES counts and mode on guide star, in and out of the aperture.
32	Spacecraft Roll	Orientation of spacecraft with respect to north.
33	Telescope Focus	Optimum=-1, good=-3 to 2.
34	Radiation	Background count rate due to particles. The rate in DN/hour is given roughly by dex(FPM).
35	Beta	Angle from the antisun (Beta=0)
36	FSS Roll	Roll angle with respect to the sun (0 degrees is the optimal roll).
37	Expo. Start	Day of year and time (U.T.) for the beginning of the exposure.
38	THDA	Camera-head temperature at the beginning of the exposure.
39	Read Start	U.T. date and time when image was telemetered to the ground.
40	Read Comments	Notation if microphonics avoidance technique was used (LWR only) or if LWP scan anomaly occurred.
41	Archive Tape	Number of archive tape.
42	Image Sequence	Camera and number of observation, uniquely identifying the image.
43	Exposure Levels	DN levels (0 to 255) for peak emission, continuum, background, and microphonic noise measured by the T.O.
44	T.O. Comments	Information on data missing from the image, microphonics, read failures, and other notations about the exposure.

Figure 2c: VILSPA Observation Log

OBSERVATORY LOG

DATE D M Y: 24 AUG 84 RAW TAPE D M: 24 AU(

PROPOSAL	OBJECT TYPE	SP.TYPE m_V	RIGHT ASCENSION DECLINATION ROLL ANGLE	RESOL.	CAMERA IMAGE NO. RAW T. FILE	FES CTS ref. p. slot undov/f.s	FOCUS BKG THDA	APERTURE	AP. SHUT.	G.M.T. hh:mm:ss	DURATION mmm:ss	CONTIN.	EM. LINES	BACKG.	COMMENTS	OBSERVER / RESIDENT ASTRONOMER
GE251	~~N145~~ 159 AS in LMC(72)	HII 14	α 05, 40, 31.1 δ −69, 46, 09 R 294, 09, 05.8	L	SWP 23771 1 + 1	130	−1.6 0.08 8.5	L	O	18:33:35	30:00	1	O	1	55 cts at RP. (PNT = −14, −203) gde (474 F.O) 1267,78 MN= FO	ISRAEL WAMSTEKER
	"	"	α , " , . δ , , R , ,	L	LWP 4072 1 + 2	"	−1.62 0.08 8.8	L	O	19:11:25	60:00	2	O	3	(1025, 915, 380 FO) Max = 60 cnt B ~ 45. MN=	
	N11A LMC 72	12	α 04, 57, 10.0 δ −66, 27, 54 R 284, 20, 35.1	L	SWP 23772 1 + 3	139 20 50	−1.96 0.08 8.8	L	O	21:12:34	~~60:00~~ 90:00	5	5	0	Gde = (1433, −94 FO 152) MN=	
			α , , δ , , R , ,	L	LWP 4073 1 + 4	122 17 5.0	−2.40 .08 9.2	L	O	22/48/21	90/0	7	0	1	Sat. 2800 − 2500 MN=	
	SK-6636 72	11.4	α 04, 57, 01 δ −66, 27, 52 R 284, 20, 35	L	SWP 23773 1 + 5	456 0 5.0.	−1.57 .08 9.5	L	O	00/25/01	22/00	3	0	0	Mk. 50 @ 1300 MN=	
			α , , δ , , R , ,		1 +										MN=	
			α , , δ , , R , ,		1 +										MN=	
			α , , δ , ,													

sure quality and the presence of spectral features. They are not suitable for measurement and should be used for quick-look inspection only.

4.5 *Photowrites*

The IUE Observatory at GSFC maintains a browse file of photographic representations of the raw, wavelength scale superposed, and linearized versions of all images read down by GSFC. In addition, photographic representations of some raw images read down by VILSPA are contained in the browse file. These photographic representations or "photowrites" are useful in assessing exposure level, presence of emission or strong absorption lines, and whether particular images are affected by missing data, cosmic rays, by radioactive decays in the camera phosphor, or microphonic noise in the camera. Photowrites are also useful for determining where the target was in the large aperture (for SWP spectra geocoronal Lyman alpha illuminates the large aperture for most exposures longer than 15 minutes in duration). Photowrites for GSFC and some VILSPA images may be requested in conjunction with an archival request to NSSDC (see below).

4.6 *Obtaining IUE Archival Data*

IUE archival data may be obtained from the National Space Sciences Data Center (NSSDC), the RDAFs, or through the IUE Observatory.

4.6.1 *Requesting Data from NSSDC*

NSSDC maintains the IUE archives for NASA. All IUE images obtained by NASA and VILSPA are available from the NSSDC, once the Principal Investigator's proprietary period of 6 months has expired. IUE data may be requested on magnetic tape at 800, 1600, or 6250 bpi. You may choose to receive all forms of the data - the raw image, the photometrically corrected image, and the extracted data - or just the extracted data. Note that the time to process requests for only extracted data is significantly less than requests for all forms of the data. You may also request photowrites suitable for quick-look analysis. The data will be the current version in the archives processed in various ways (see section 4.5 below). If the data were obtained and processed in the first few years of IUE's operation, you may wish to ask to have the data reprocessed using the current version of the image processing software and calibrations (see section on requesting reprocessed data).

To request data on tape and/or photowrites (photowrites are available for GSFC images and some early VILSPA images) , please fill in and submit a copy of the form provided (see Figure 4a). A suitable number of magnetic tapes to contain the data should be included with your request. Also, for researchers requesting a large number of spectra, a fee for processing costs may be charged to you. A limited amount of data may also

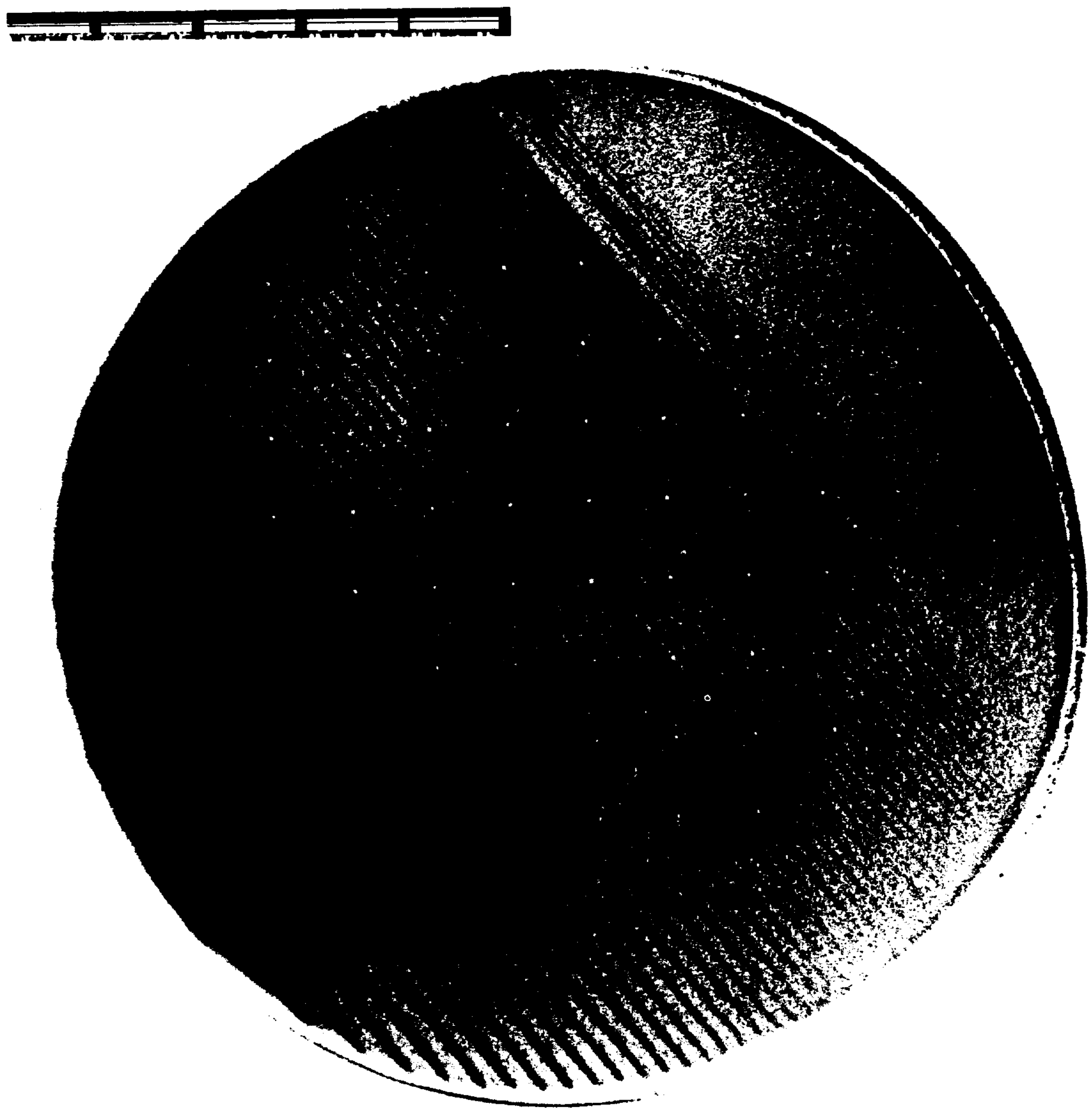


Figure 3a: A Raw high dispersion SWP image photowrite

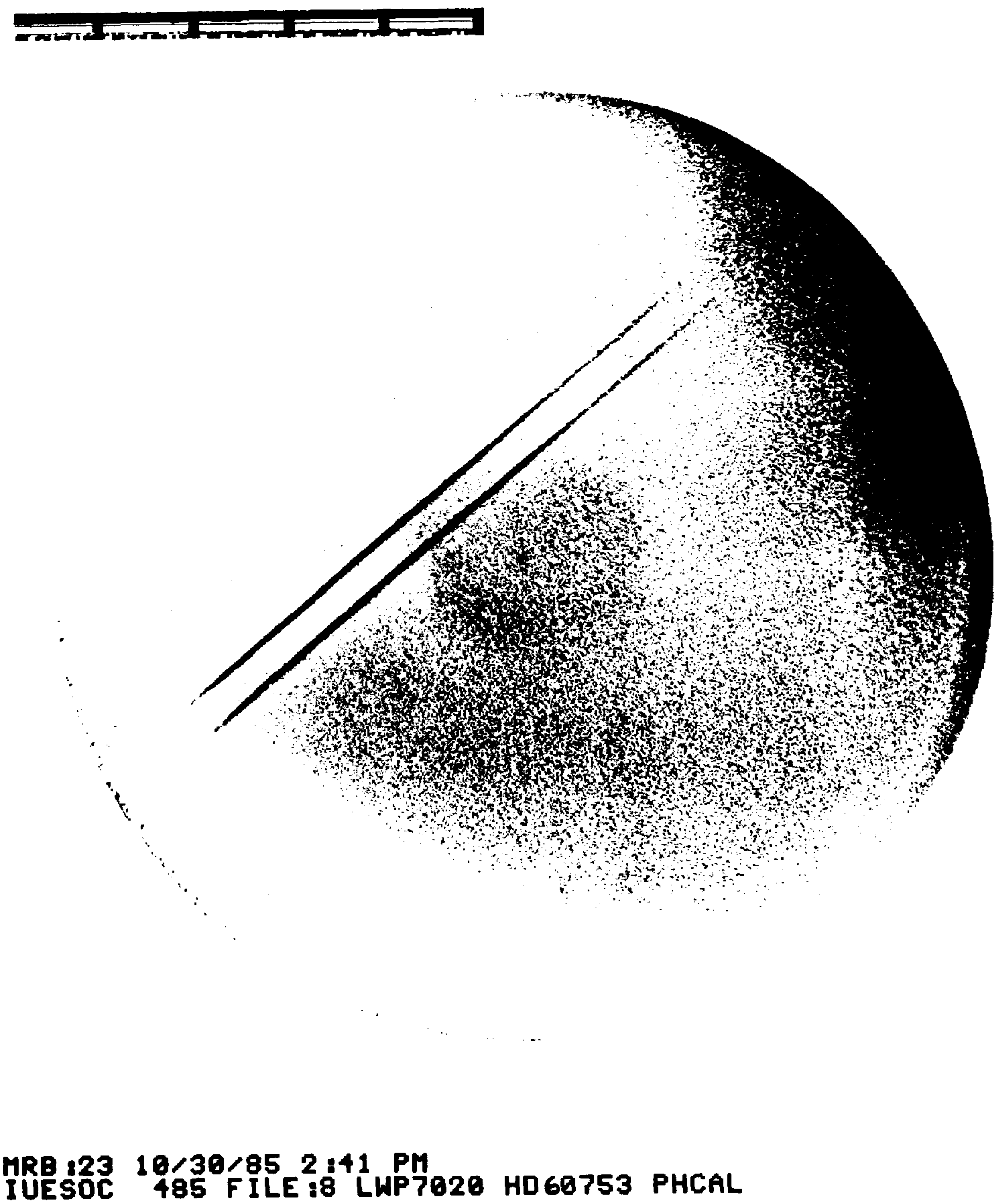
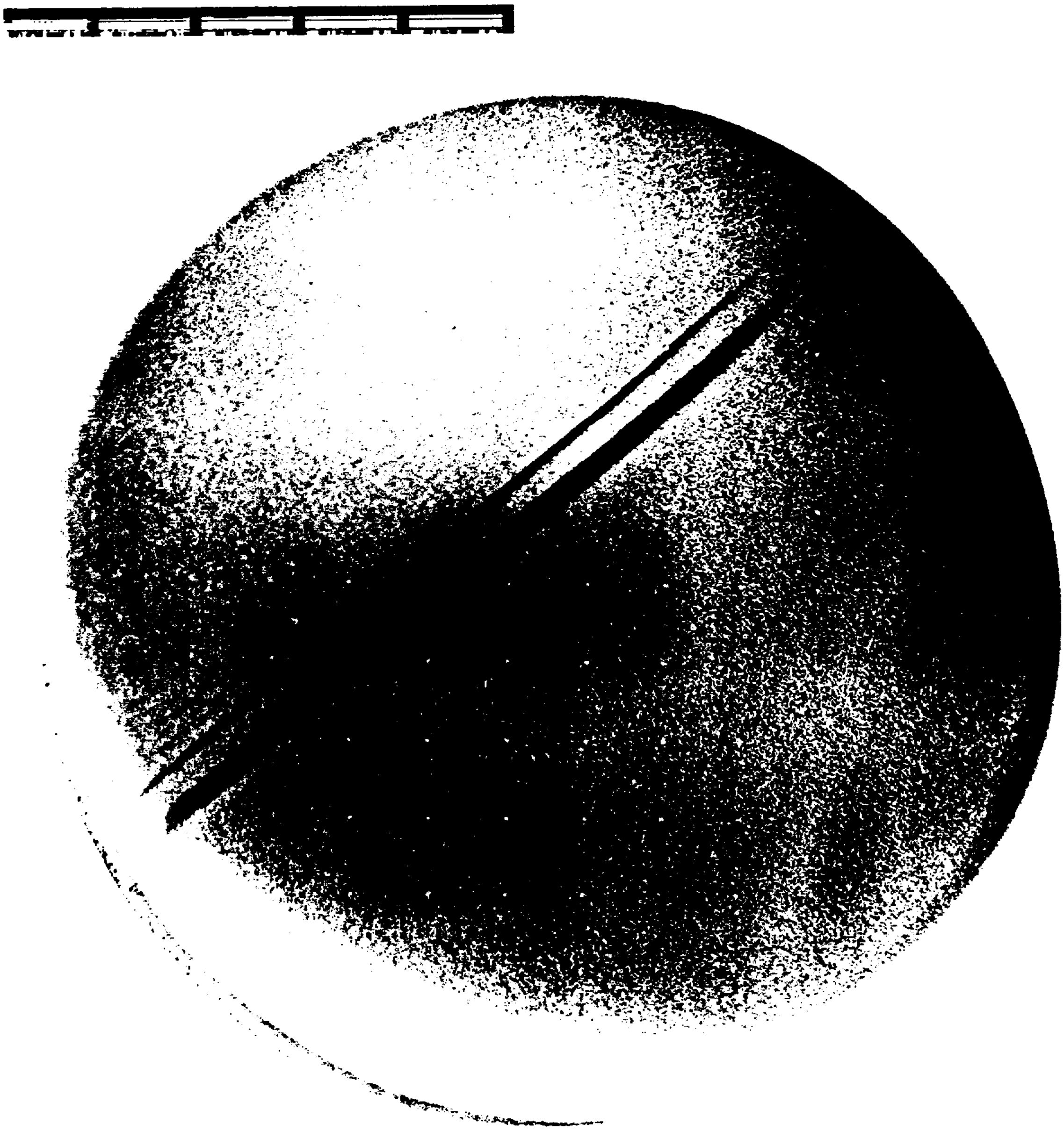


Figure 3b: A Raw low-dispersion LWP point source image photowrite with observations made in both apertures



JW:34 8/20/84 8:14 AM
IUESOC 5696 FILES: 1 LWP4019 HD127972 HSGCG

Figure 3c: A Raw low-dispersion Lwp trailed large aperture and point source small aperture photowrite be requested and transmitted to you via the SPAN network. Information on requests for IUE data from NSSDC and SPAN access should be addressed to Ms. Charleen Perry (telephone 301-286-6695, SPAN address NSSDCA::PERRY). Typical small and mid-size orders take 4 - 6 weeks.

4.6.2 *Requests for Extracted Spectra from The Condensed Data Archive (CDA)*

The IUE Observatory, through the RDAF, provides extracted spectra to requesters directly from the IUE CDA. This service is most suitable when relatively small amounts of extracted data are required on tape only. Copies of the current version of the extracted data in the IUE archives are sent on magnetic tape to the requester within a week or so. Alternatively the tape(s) can be held at the Observatory for pickup during your IUE observing run, or at the RDAF for a subsequent visit. Tape densities of 800 bpi, 1600 bpi, and 6250 bpi are available.

Requests may be made by mail, by telephone, or via computer message to the RDAF staff. You may also wish to use a version of the attached form, titled " IUE Data Request Form" (see Figure 4b), for your CDA request; check off the " Extracted Data" column. Priority will be given to requests for data required for IUE support programs, either observing programs under the Space Astrophysics Data Analysis Program (SADAP) or Astrophysics Data Program (ADP). Therefore, please note the appropriate program ID on the form. Further information may be requested from Mr. Randy Thompson (telephone 301-286-8800, SPAN address IUE::RTHOMPSON).

4.6.3 *Using IUE Data at the Regional Data Analysis Facilities (RDAFs)*

The staff at the RDAFs, located at Goddard and at the University of Colorado, will obtain IUE data for visitors. You may request specific images when you call to schedule your visit to the RDAF. If sufficient notice is given (a few days), the data will be obtained and loaded into your RDAF computer account prior to your arrival. If the data you wish to analyze have been recently obtained with IUE and thus is not yet releasable, we ask that you bring along your Guest Observer tapes or arrange to have them held at the Observatory during your observing run. If your analysis of the data is part of an IUE-supported program, we ask that you let us know the program ID for our records.

The RDAFs can provide you with low-dispersion spatially resolved data (LBLS or ELBL files), low-dispersion slit-integrated spectra (MELO or ESLO), and/or extracted high-dispersion spectra (MEHI or ESHI). You may also browse through the IUE Merged Log of observations to choose the data relevant to your analysis. Remote access via SPAN and telephone line is available to experienced RDAF users. Further information may be requested from Mr. Randy Thompson at the Goddard RDAF (telephone 301-286 8800, SPAN address IUE::RTHOMPSON) and from Dr. Ed Brugel at the Colorado RDAF (telephone 303-492-4054, SPAN address CYGNUS::BRUGEL).

4.6.4 *Requesting Reprocessing of Archival IUE Data*

Astronomers analyzing archival IUE data frequently find that their spectra are more useful if they have been reprocessed using the most up-to-date version of the image processing software and calibrations. In general, data processed during 1982 or earlier benefit most from reprocessing. Details of the changes to the image processing system may be found in articles listed in the references at the end of this section. A summary of the major changes to the image processing system thus far is given in chapter 3 of this manual.

Please use the following procedure to request reprocessed archival data. You should send a copy of the form "IUE Request Form"(see Figure 4b) to the IUE Operations Scientist to request reprocessing of IUE data. Please check off the data products you require under the "Reprocessed Data" column. Magnetic tapes can be provided at 800, 1600, or 6250 bpi. Normally IUE Guest Observer tape format is used for the magnetic tapes, but FITS format may be requested.

Photowrites and CalComp plots can be generated if needed. However these latter data products require more time to prepare, so you may wish to request them only if you really need them. It will expedite delivery if large requests are broken into several smaller requests; please note which spectra are needed most urgently and which can be supplied at a later date. The Observatory will provide magnetic tapes for your data; you are asked to return the tapes when you are finished with them. The data products will be shipped directly to you, rather than through the NSSDC as has been done in the past.

All requests for reprocessing will be reviewed to insure that the Observatory can provide the necessary resources and to identify any special or unusual requests. Priority will be given to requests for data required for IUE supported programs, either observing programs or archival programs under the Space Astrophysics Data Analysis Program (SADAP) or Astrophysics Data Program (ADP). Therefore please note the appropriate program ID on the form. Further information may be requested from Dr. Myron Smith (telephone 301-286-7346, SPAN address IUE::MSMITH).

4.6.5 *Requests for Raw Images Only*

In some special cases, astronomers may wish to have available the raw images for some spectra. It is possible, for instance, to call up a raw image on an image display system for inspection of exposure levels, radiation hits, and so forth. The creation of a new facility at Goddard permits the Observatory to obtain copies of the raw images quickly. Requests for tapes of raw images will be filled on request. Please use the "IUE Data Request Form" (Figure 4b), and check off "Raw Image" for such requests.

Requests for raw images will be reviewed to insure that the Observatory can provide the necessary resources and to identify any special or unusual requests. Priority will be given to requests for data required for IUE supported programs, as described above. Therefore please note the appropriate program ID on the form. For further information, please contact Dr. Myron Smith (telephone 301- 286-7346, SPAN address IUE::MSMITH).

References

Sonneborn, G., Oliversen, N.A., Imhoff, C.L., Pitts, R.E., and Holm, A.V. 1987. "IUE Observers Guide", *NASA IUE Newsletter* No. 32.

IUE DATA REQUEST FOR RELEASABLE IMAGES

Name:* ______________________________ Requested Tape Density:† ( ) 800 bpi

Address: ______________________________ ( )1600 bpi

______________________________ ( )6250 bpi

______________________________ Telephone: __________ Extracted spectra only: ( )††

Object	Image Seq. No.**		Check desired medium	THESE SPACES FOR NSSDC/WDC-A USE ONLY		
	Cam.	Image No.	Photowrite Mag. Tape			

* Please give full name (first, middle initial, last) and title (Dr., Prof., Mr., Ms., etc.)
† Maximum density that can be processed at you installation. Supply appropriate number of tapes (new 2400-ft.)
†† Raw and geometrically/photometrically corrected images not supplied. Processing time and amount of tape will decrease significantly
** Please indicate VILSPA (European) images by placing a "V" after the image number

Image Capacities for 2400-foot tapes

Images	6250	1600	800 bpi
Full	15	8	5
Extracted	50	20	15

INTENDED USE OF DATA (Check all that apply)

_ Support of a NASA effort
_ Support of a U.S. Government effort
_ Research and Analysis Project
_ Educational purposes
_ Use in publication

Send this form with the appropriate number of tapes to:

Domestic: Request Coordination
National Space Science Data Center
Code 633.4
NASA Goddard Space Flight Center
Greenbelt, MD 20771

Foreign: Request Coordination
World Data Center A for Rockets & Satellites
Code 630.2
NASA Goddard Space Flight Center
Greenbelt, MD 20771 USA

Figure 4a: NSSDC Data Request Form

Page ___ of ___

IUE Data Request Form

Name ______________________________ Date ______________________________

Institution ______________________ Please distribute data products re:

Telephone ________________________ [ ] hold at GSFC RDAF for visit on

date ______________________.

Is this data request for a NASA/IUE supported program? If so, higher priority will be given in filling the request. Please note the relevant IUE observing program code(s) or SADAP code(s) here:

[ ] name and address given below:

____

____

____

____

Please specify the data and data products requested below. The current version of the data in the archives will be sent to you unless reprocessing is requested below. Mail this form to: Dr. Donald K. West, Code 684, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771.

Object Name	Camera	Image Number	Raw Image	Extracted Data (Existing Version)	Reprocessed Data Mag Tapes	Photo-writes	CalComp Plots

*Please specify tape density: [ ] 800 bpi [ ] 1600 bpi [ ] 6250 bpi (when avail)

For staff use:

Figure 4b: IUE Data Request Form

Chapter 5

Reducing the Data

The final reduction of your IUE data can be outlined in several steps.

Reading the Data

- reading the G.O. tape
- understanding the file structure
- interpreting the science image header and processing information

Checking for Problems

- checking for acquisition or data transmission problems
- checking to see whether the data are affected by a calibration or image processing error
- correcting errors
- identifying blemishes in the data

Extraction and Application of Corrections

- extracting the spectral data
- applying the corrections necessary to produce accurate absolutely calibrated spectra on a wavelength or radial velocity scale
- compensating for camera sensitivity degradation
- correcting for interstellar extinction

Once these inspections, extractions, and corrections have been made, the scientist can concentrate on making the necessary measurements. Due to the complexity of reading and interpreting IUE data we strongly urge first time users of IUE data to visit one of the RDAFs.

5.1 *G.O. Tape Format*

The G.O. tape format is described in detail in section 8.2 of Turnrose and Thompson (1984), and also in Turnrose, Harvel and Stone (1981), Munoz Piero (1985). Those researchers wanting to write their own software to read the tape should become thoroughly familiar with the contents of this section. RDAF users do not need to be concerned with the tape structure since the RDAFs provide software to access the data on the G.O. tape. Please refer to section 3 for a discussion of the "new" software versus the "old" software.

5.1.1 *High Dispersion Data*

Guest-Observer Tape Organization for Each Image:

File Type	Old Software	New Software
raw image	RI	RI
photometrically corrected image	GPI	PI
extracted spectral image	ESHI	MEHI

The RDAFs use the data from the extracted spectrum file. Since the echelle blaze and absolute sensitivity calibration data are derived from data which have been processed and extracted with the IUESIPS software, these calibrations are suitable for application to other data which have also been processed with IUESIPS. These calibrations may not be valid for spectra which have been extracted using other software. Alternate extraction schemes do exist at other facilities (e.g. STARLINK) which work with the photometrically-corrected image, but are not currently available at the RDAFs.

5.1.2 *Low Dispersion Data*

Organization of Low-Dispersion Data on Guest Observer Tapes:

File Type	Old Software	New Software	New ELBL Software
raw image	RI	RI	RI
photometrically corrected image	GPI	PI	PI
geometrically and photometrically corrected image segment	GPIS		
spatially-resolved extracted data	ESSR	LBLS	ELBL
extracted spectral data	ESLO	MELO	MELO

If both apertures were processed for a particular low-dispersion observation there will be two spatially-resolved and extracted-spectral data files, one for each aperture. At present, only the spatially-resolved (line-by-line) and extracted spectra are used at the RDAFs. The low-dispersion absolute-sensitivity calibration assumes that the IUESIPS spectral extraction and slit integration has been done. Users of nonstandard slit-integration techniques should exercise caution before applying the calibrations presented in the NASA IUE Newsletter for either the absolute sensitivity or camera degradation.

5.2 *Interpreting the Science Image Header*

Important information on the spacecraft status, the way the observation was obtained, and the subesquent processing of the spectral data is archived with each spectral image in the form of a science image header. The amount of information stored in the header and its location have changed in the course of the IUE mission with the gradual evolution of the image processing and operations systems. Early images, in particular, may not contain all of the information needed to fully specify the way the data was taken, or the condition of the spacecraft at the time of observation. The files are stored as a mixture of EBCDIC and binary data. See section 8.1 in Turnrose and Thompson (1984) for information on reading the science image headers. Figures 5a and 5b and Table 5 (reproduced from Turnrose and Thompson 1984) show the science image header information for a raw image. Figure 6 shows the image processing information for a merged extracted low dispersion spectrum (MELO). Figure 7 shows the image processing information for a high-dispersion extracted spectrum (MEHI). The information in the science image header can be in error, particularly the hand-entered comments in lines 3-9 and the preplanned target data in lines 36-37. A small number of images (n $<$ 300) in the archives were recovered from the IUE ground system's tapes of spacecraft telemetry ("history tapes") when hardware or software problems prevented the data from being properly archived in real-time. The headers of such "history replay" images are typically 95 percent blank or grossly incorrect since information stored in the ground system during the observation is no longer available. Critical data which may be missing or incorrect (date and time of observation, exposure time, target coordinates, etc.) are usually corrected manually before the image is processed. The observing script is usually the definitive source of correct information, especially when the image header may be in error. The IUE merged log information is another reliable source of information for the exposure description. Caution must be taken when analyzing history replay images: some camera, spacecraft, and ground system data, normally used to accurately process the image, are not recorded on the history tape and are usually permanently lost. It is important to check that all critical data are in agreement. Highlights of the image header contents are described below.

5.2.1 *Line 1*

System label. The last 8 digits give the observing station, camera ID, dispersion, and image number, eg. 013122770 is a GSFC observation in low dispersion of SWP 22770. (See 7-10 in Figure 5a and Table 5).

5.2.2 *Line 2*

Image parameters. The sixth field between asterisks gives the total commanded exposure time in seconds. (See 15 in Figure 5a and Table 5). If both large and small aperture spectra were obtained, the sum of the exposure times is given.

5.2.3 *Lines 3 - 9*

Lines 3-9: "Astronomer comments" entered by the Telescope Operator. Line 3 for NASA images normally includes the image number, object name, exposure time, aperture, and dispersion. Line 4 includes comments about telemetry losses, heater warmups, etc. Line 7 gives the observer, program and date. VILSPA images code the same information slightly differently.

5.2.4 *Lines 10 - 32*

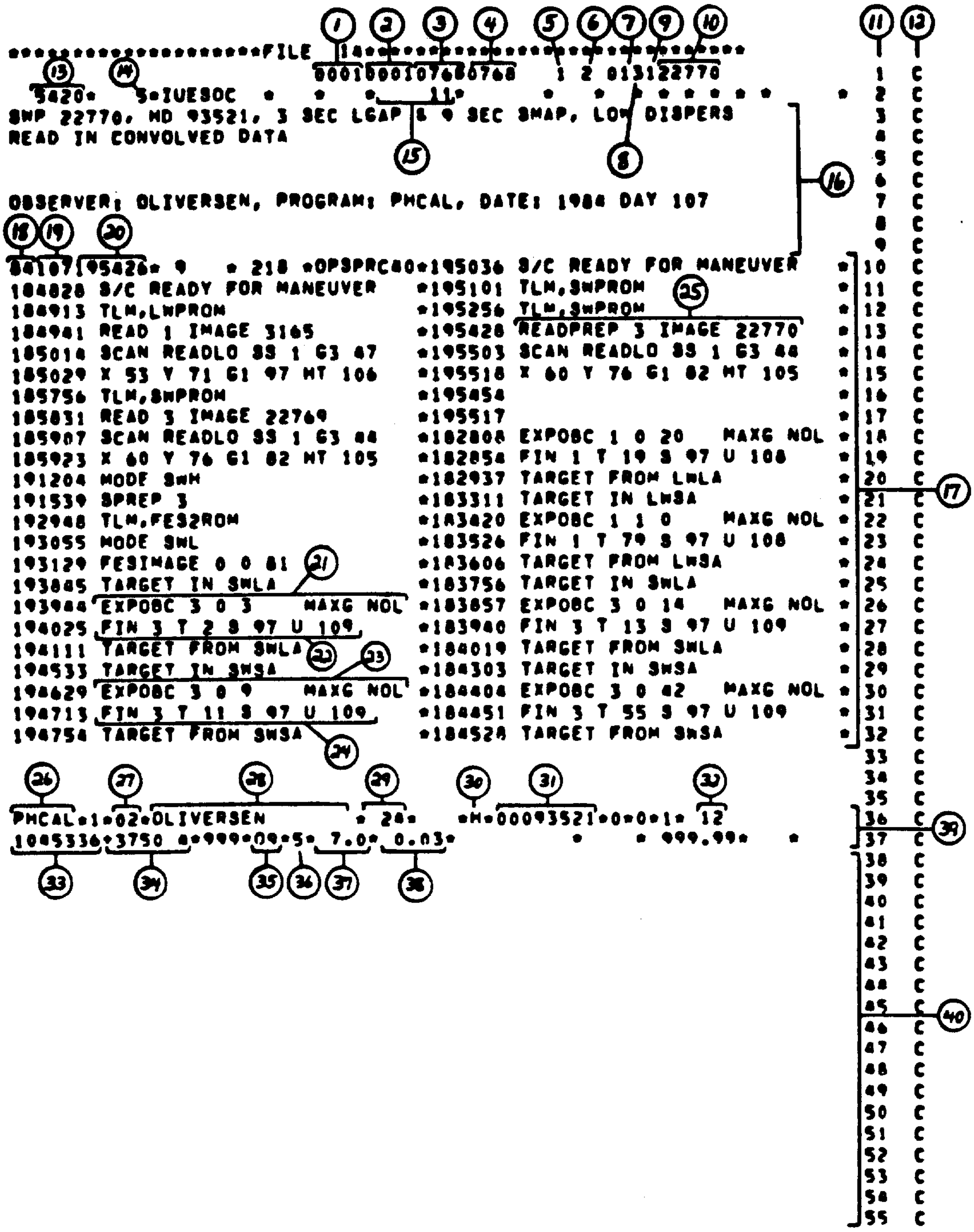
Lines 10-32: Event status and procedures. These lines are stored automatically by the IUE ground system as the observations are made. Line 10 lists the year, day, hour, min, sec (UT) of the read, camera data base version, and operations procedure file. Thereafter recent commands to the spacecraft which have been executed up until the read time are listed. The oldest entries are separated from later entries by double blank lines. The event round robin is a record of the important commands issued by the telescope operator, combined with critical spacecraft and ground system data needed to properly document the observations. If a long exposure were underway and there were considerable activity with other images, the data applicable to the image of interest may have rolled out of the event round robin.

References

Munoz Piero, J.R. 1985. *Nasa IUE Newsletter*, No. 27, 27.

Turnrose, B.E., Harvel, C.A., and Stone, D.F. 1981. *IUE Image Processing Information Manual, Version 1.1 (Old Software)*, CSC-TM81-6268.

Turnrose, B.E., and Thompson, R.W. 1984. *International Ultraviolet Explorer Image Processing Manual, Version 2.0 (New Software)*, CSC-TM84-6058.



```
*********************FILE 14*************************************
                            00010001076807 68   1 2 013122770
 5420*   5*IUESOC  *   *   *   11*    *   *   *  *  *  *  *  *     *
SWP 22770, HD 93521, 3 SEC LGAP & 9 SEC SMAP, LOW DISPERS
READ IN CONVOLVED DATA


OBSERVER: OLIVERSEN, PROGRAM: PHCAL, DATE: 1984 DAY 107

84107195426* 9    * 218 *OPSPRC40*195036 S/C READY FOR MANEUVER    *
184828 S/C READY FOR MANEUVER    *195101 TLM,SWPROM                *
184913 TLM,LWPROM                *195256 TLM,SWPROM                *
184941 READ 1 IMAGE 3165         *195428 READPREP 3 IMAGE 22770    *
185014 SCAN READLO SS 1 G3 47    *195503 SCAN READLO SS 1 G3 44    *
185029 X 53 Y 71 G1 97 HT 106    *195518 X 60 Y 76 G1 82 HT 105    *
185756 TLM,SWPROM                *195454                           *
185831 READ 3 IMAGE 22769        *195517                           *
185907 SCAN READLO SS 1 G3 44    *182808 EXPOBC 1 0 20    MAXG NOL *
185923 X 60 Y 76 G1 82 HT 105    *182854 FIN 1 T 19 S 97 U 108     *
191204 MODE SWH                  *182937 TARGET FROM LWLA          *
191539 SPREP 3                   *183311 TARGET IN LWSA            *
192948 TLM,FES2ROM               *183420 EXPOBC 1 1 0     MAXG NOL *
193055 MODE SWL                  *183526 FIN 1 T 79 S 97 U 108     *
193129 FESIMAGE 0 0 81           *183606 TARGET FROM LWSA          *
193845 TARGET IN SWLA            *183756 TARGET IN SWLA            *
193944 EXPOBC 3 0 3     MAXG NOL *183857 EXPOBC 3 0 14    MAXG NOL *
194025 FIN 3 T 2 S 97 U 109      *183940 FIN 3 T 13 S 97 U 109     *
194111 TARGET FROM SWLA          *184019 TARGET FROM SWLA          *
194533 TARGET IN SWSA            *184303 TARGET IN SWSA            *
194629 EXPOBC 3 0 9     MAXG NOL *184404 EXPOBC 3 0 42    MAXG NOL *
194713 FIN 3 T 11 S 97 U 109     *184451 FIN 3 T 55 S 97 U 109     *
194754 TARGET FROM SWSA          *184528 TARGET FROM SWSA          *

PHCAL*1*02*OLIVERSEN            * 24*    *H*00093521*0*0*1* 12
1045336*3750 4*999*09*5* 7.0* 0.03*          *      * 999.99*     *
```

Figure 5a: Print of science image header for raw image (RI) file. (Reproduced from Turnrose and Thompson, 1984)

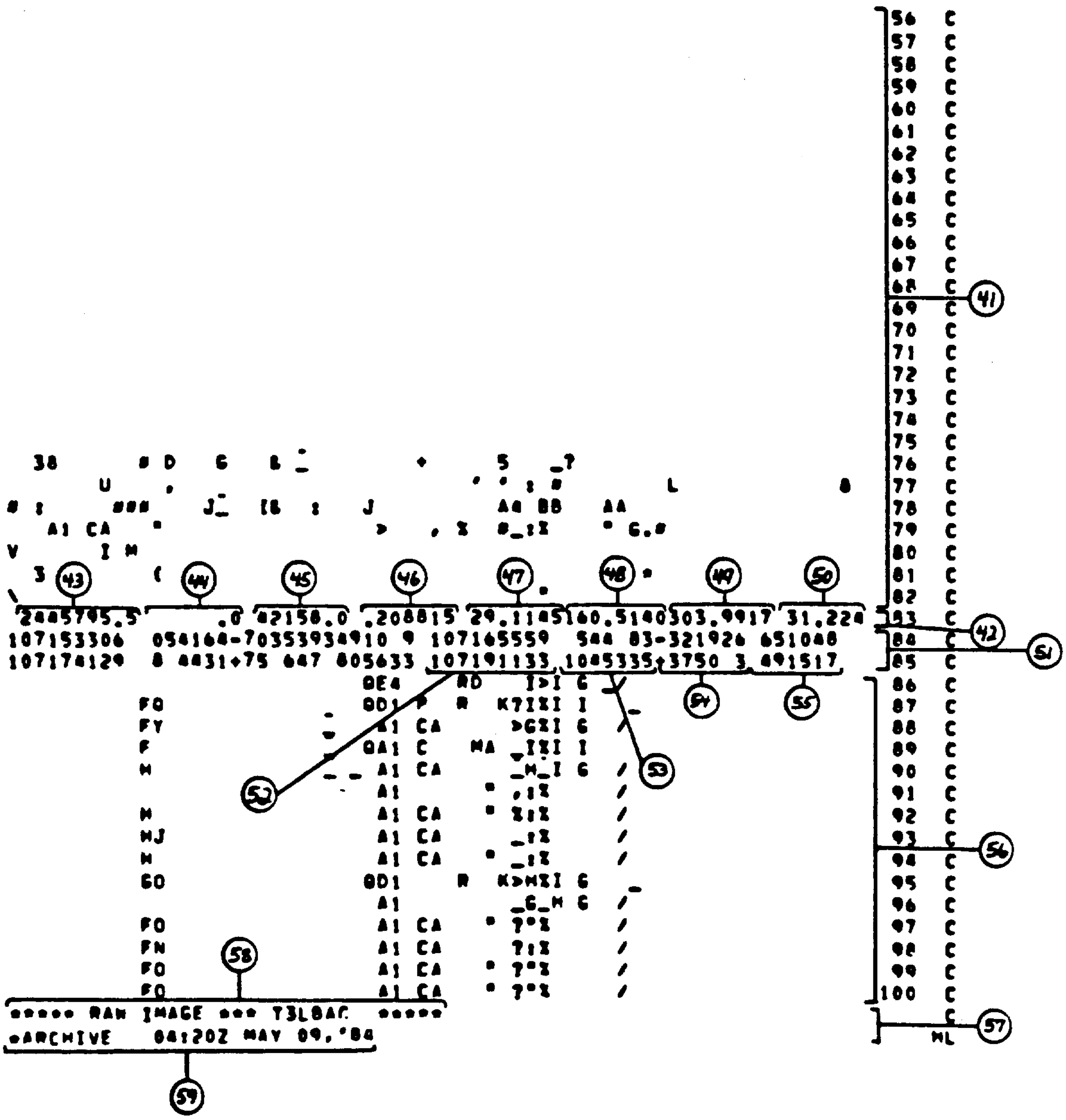


Figure 5b: Continuation of print of science image header for raw image (RI) file. (Reproduced from Turnrose and Thompson, 1984)

Table 5: Key to Figures a-b (1 of 3) (from Turnrose and Thompson, 1984)

Field No.	Contents	
1	Starting line (record no.) of data file	(bytes 25 - 28)
2	Starting sample (byte no.) of data file	(bytes 29 - 32)
3	Number of lines (records) in data file	(bytes 33 - 36)
4	Number of samples (bytes per record) in data file. Fields 1-4 collectively comprise the "size parameters" for the data file.	(bytes 37 - 40)
5	Camera scan step size (1-4)	(byte 44)
6	EDS file no. (1 or 2)	(byte 46)
7	Station flag (0 = HANDOVER, 1 = GSFC, 2 = VILSPA)	(byte 49)
8	Camera no. (1 = LWP, 2 = LWR, 3 = SWP, 4 = SWR, 8 = FES1, 9 = FES2)	(byte 50)
9	Dispersion flag (0 = high, 1 = low)	(byte 51)
10	Image sequence no. (1-99999)	(bytes 52 - 56)
11	Running number of label line	(bytes 67 - 69)
12	Continuation character (C = more lines follow, L = this is last line of label)	(byte 72)
13	SOC tape (raw image archive tape) no.	
14	File no. of raw image on SOC tape	
15	Total time camera was turned on (seconds), taken from FIN entry (see field no. 24). Sum of all exposures if more than one is taken. This is not a true exposure time for trailed spectra.	
16	Guest Observer comments section, entered by telescope operator	
17	Event "round-robin" section describing time-tagged sequence of procedures. Entries all begin with GMT time in hhmmss format. Oldest entries appear below the double blank lines. Note: SWLA = short wavelength large aperture, LWSA = long wavelength small aperture, etc.	
18	Year of read	
19	GMT day of read	
20	Approximate time of read in hours, minutes, and seconds GMT	

Table 2: Key to Figures a-b (2 of 3) (from Turnrose and Thompson, 1984)

Field No.	Contents
21	Exposure start tag. GMT time given is near start of exposure. Format is: EXPOBC cam. no. $t_{min}t_{sec}$ gain lamps where $t_{min}t_{sec}$ is the commanded duration of "camera-on" time (seconds are rounded). Actual duration may be modified by a subsequent MODTIME command.
22	Exposure end tag. GMT time given is usually near end of exposure but can be much later. Format is: FIN cam. no. T t S sec voltage U uvc voltage, where t is the total cumulative duration of "camera-on" time achieved in seconds (truncated) since last read of camera in question. Due to truncation, duration may not agree with that in EXPOBC tag.
23	Exposure start tag, in this case for the second aperture.
24	Exposure end tag, in this case following exposure in second aperture and showing truncated cumulative time for both apertures. Time in seconds here is passed to field no. 15.
25	Readprep tag. GMT time given is near start of image read process. Format is: READPREP cam. no. IMAGE image sequence no.
26	Program ID
27	Episode no. (1, 2, 3,. . . etc.)
28	Observer sign on name
29	Target list sequence no.
30	Catalog source (H, B, D,. . . etc.)
31	Object name
32	Object classification
33	Right ascension of object (hhmmsst where t is tenths of seconds of time)
34	Declination of object (± ddmmss of arc)
35	Spectral type
36	Luminosity class (1-9)

Table 2: Key to figures a-b (3 of 3) (from Turnrose and Thompson, 1984)

Field No.	Contents
37	V magnitude or flux
38	Color excess E(B-V) or color B-V
39	Information from Preplanned Observation Tape (POT)
40	Binary section of label
41	Binary section of label
42	Orbital elements, periodically updated, for epoch specified by fields 43 and 44
43	Julian Date
44	Seconds since midnight of JD in field 43
45	a, semimajor axis (km)
46	e, eccentricity
47	i, inclination (deg)
48	Ω, longitude of ascending node (deg)
49	ω, argument of pericenter (deg)
50	M, mean anomaly (deg)
51	Spacecraft attitude commands sent to spacecraft (most recent set of four)
52	Day:hour:min:sec at which new attitude commanded
53	Right ascension commanded (hhmmsst where t is tenths of seconds of time)
54	Declination commanded (± ddmmss of arc)
55	Spacecraft roll angle (dddmmss of arc)
56	Binary section of label
57	Image processing history section of label
58	File type identifier and image processing scheme name (see Figure 9-2 and Table 9-2)
59	Identifier for image processing program name and time (GMT) of image processing scheme initiation

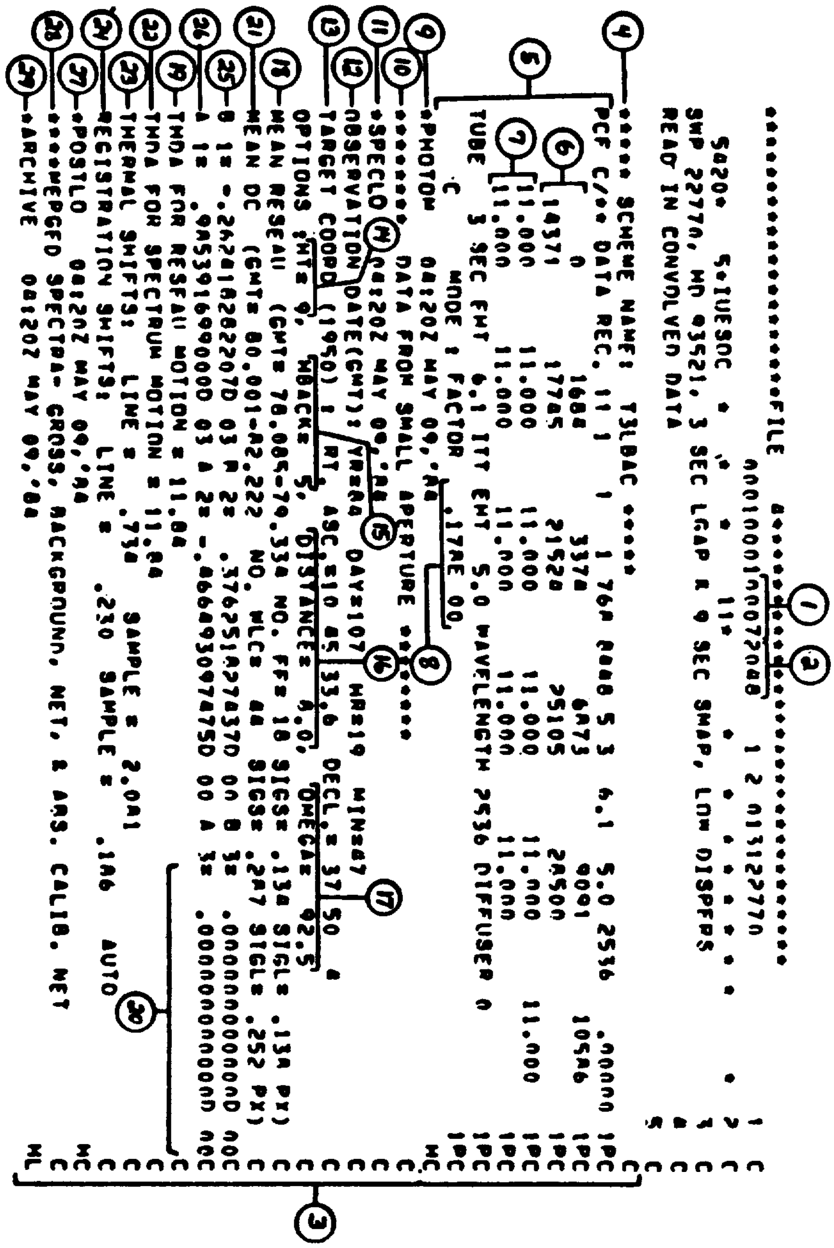


Figure 6: Listing of image processing information for low dispersion Extracted Spectral File (MELO) (reproduced from Turnrose and Thompson, 1984)

Table 3: Key to Figure 6 (1 of 2) (from Turnrose and Thompson, 1984)

Field No.	Contents
1	Number of records in data file
2	Number of bytes per record in data file
3	Image processing history section of label
4	Image processing scheme name, in format shown below.

(1)	(2)	(3)	(4)	(5)	(6)
T	n	H	L	A	C
		L	S	M	S
			B		
			E		
			T		
			X		
			Y		

(1) T = new software (F formerly used for old software)
(2) n = camera number (1-4)
(3) H = high dispersion
L = low dispersion
(4) L = large aperture point source
S = small aperture point source
B = both apertures point source
E = large aperture extended source
T = large aperture trailed source
X = both apertures extended source
Y = both apertures trailed source
(5) A = automatic registration of spectral order(s)
M = manual registration of spectral order(s)
(6) C = current production processing calibration
S = special calibration

Note: not all combinations are possible.

Field No.	Contents
5	Data pertinent to ITF application (see Section 5)
6	Effective ITF exposure times in units of 0.01 seconds
7	ITF MULT values
8	ITF FACTOR value (rounded)
9	Identifier for image processing program name and time
10	Descriptor identifying aperture from which spectrum was extracted
11	Identifier for image processing program name and time
12	GMT "midpoint" of observation (see Section 6.4.1)

Table 3: Key to Figure 6 (2 of 2) (from Turnrose and Thompson, 1984)

Field No.	Contents
13	Target coordinates extracted from line 37 of raw-image label (fields 33 and 34 in Figure 9-1)
14	Height (length) of gross extraction slit in units of $\sqrt{2}$ pixels (see Section 7)
15	Height of background extraction slit in units of $\sqrt{2}$ pixels (see Section 7)
16	Distance from dispersion line to center of background slit in units of $\sqrt{2}$ pixels (see Section 7)
17	Value of "OMEGA" angle in low dispersion extraction (angle of the line of constant wavelength relative to dispersion direction) (see Section 7)
18	Identification of mean reseau data set (see text)
19	THDA temperature used for reseau correction
20	Space for message if no reseau temperature correction was applied (see Figure 9-3).
21	Identification of mean dispersion constant set (see text)
22	THDA temperature used for dispersion-constant correction
23	Values of time/temperature computed shifts applied to zero point of dispersion relations
24	Values of residual shifts applied (either manually or automatically) to zero point of dispersion relations to register spectrum
25	Array of line-direction dispersion-constant values (after <u>all</u> shifts) used to extract spectrum
26	Array of sample-direction dispersion-constant values (after <u>all</u> shifts) used to extract spectrum
27	Identifier for image processing program name and time
28	File-type identifier message
29	Identifier for image-processing program name and time

```
********************FILE  22*******************************
                  000100010325208R   1 1 012017371              1  C
  5413*   A*IUESOC  *   *   *     6*     *   *  * * * * * *    *  2  C
LWR 17371, HD 149438 (TAU SCO), 6 SEC, HIGH DISP, LG APER          3  C
                                                                   4  C
                                                                   5  C
*MICRO    10:44Z APR 17,'84                                          MC
PING! MICROPHONICS, AFFECTED LINES:  353 TO  360                      C
***** SCHEME NAME:  T2HLAC *****                                      C
PCF C/** DATA REC. 12 1    1    1 768 9216 5 2  6.1  5.0 2536   .00000 1PC
         0       2303      4069      8008      10073      11878       1PC
     15883      20149     24471     29391      34333      42032       1PC
    17.000     17.000    17.000    17.000     17.000     17.000       1PC
    17.000     17.000    17.000    17.000     17.000     17.000       1PC
TUBE   2 SFC EHT  6.1 ITT EHT  5.0 WAVELENGTH 2536 DIFFUSER 0          1PC
     C      MODE : FACTOR   .283E 00                                  1PC
*PHOTOM   10:44Z APR 17,'84                                          MC
********  DATA FROM LARGE APERTURE  *****************                 C
*SPECHI   10:44Z APR 17,'84                                          MC
MEAN RESFAU  (GMT= 78.073-79.204 NO. FF= 15 SIGS= .184 SIGL= .151 PX)  C
MEAN DC   (GMT= 80.001-82.222  NO. WLC=  47  SIGS= .197 SIGL= .374 PX)  C
B 1=  .15429780904800 05 B 2= -.2774578415610 00 B 3=  .9077724306570-06C
B 4=  .5925811878050-01 B 5=  .2260993410230 00 B 6= -.8019420360640-08C
B 7=  .4017085561530-08 B 8=  .0000000000000 00 B 9=  .0000000000000 00C
A 1= -.4895812934530 04 A 2=  .1472791022260 00 A 3= -.5522146305210-06C
A 4=  .7449215787830-02 A 5=  .2767349997270 00 A 6=  .2920103076530-08C
A 7=  .1110510384890-06 A 8=  .0000000000000 00 A 9=  .0000000000000 00C
THDA FOR RESFAU MOTION = 12.84                      MEAN RESFAU USED   C
THDA FOR SPECTRUM MOTION = 12.51                                       C
THERMAL SHIFTS:   LINE =   .158   SAMPLE =  -.931                      C
REGISTRATION SHIFTS:   LINE =  1.191  SAMPLE =  1.636    AUTO          C
***** EXTRACTED SPECTRUM FOR POINT SOURCE *****                        C
*SORTHI   10:44Z APR 17,'84                                            C
RIPPLE CONSTANTS: K= 230012.0 +17.25*M -.0599*M**2      A= .896        C
OBSERVATION DATE(GMT): YR=84  DAY=108  HR=23  MIN= 1                   C
TARGET COORD. (1950):  RT. ASC.=16 32 45.9  DECL.= -28  6 51           C
IUE VELOCITY (KM/S):      VX= -3.3  VY= -1.9  VZ=   .6                 C
EARTH VELOCITY (KM/S):    VX= 11.7  VY=-25.0  VZ=-10.9                 C
NET VELOCITY CORRECTION TO HELIOCENTRIC COORD.= 24.2                   C
*ARCHIVE   10:44Z APR 17,'84                                          ML
```

Figure 7: Listing of image processing information for High Dispersion Extracted Spectral File (MEHI) (reproduced from Turnrose and Thompson, 1984)

Table 4: Key to Figure 7 (from Turnrose and Thompson, 1984)

Field No.	Contents
1	Identifier for image processing program name and time
2	Microphonics presence indicator; listed are lines of raw image affected by detected microphonics.
3	Ripple correction K value, evaluated by the expression given, where M = echelle order number
4	Ripple correction α value
5	Satellite velocity components
6	Earth velocity components
7	Net radial velocity correction which was applied to extracted wavelengths (km s^{-1})

Chapter 6

The IUE Regional Data Analysis Facilities

The IUE Regional Data Analysis Facilities are available to all astronomers wishing to analyze IUE archival or current observing program data. One facility is located at the IUE Observatory at Goddard Space Flight Center and provides an opportunity for astronomers to reduce IUE data in conjunction with an observing run. The other facility is located at the University of Colorado in Boulder. Both RDAFs offer similar hardware and software and have experienced IUE users who can advise visitors on the best ways to reduce their data. The Boulder facility is particularly suited to astronomers wishing to make an extended visit. At the GSFC RDAF, proximity to the observatory means that the photowrite browse file is available and questions on the spacecraft and science instrument performance, image processing, calibration, and observation techniques can be easily handled. The GSFC facility can also offer priority processing of images during an observing run for subsequent analysis at the RDAF.

6.1 *RDAF Software*

The RDAFs have an extensive selection of software in the following areas.

Data Selection and Requests:

- searching the merged log for appropriate observations
- obtaining requested spectra from either on-site tape archives (CURDAF) or from the Condensed Data Archive (GSFC)
- quick-look evaluation by examining binned fluxes from low-dispersion spectra in pre-selected 30, 100 and 200 Å bandpasses (useful for estimating exposure times for both IUE and HST)

- ability to browse through the archived data

Assessing Data Quality:

- determining whether the spectral data quality in a particular image is affected by any errors or changes in the calibration or image processing
- display of spatially-resolved (line-by-line) data for low-dispersion spectra, which is particularly useful in identifying cosmic ray hits, telemetry dropouts, and microphonics prior to analysis
- display of missing or bad data in an image from information stored in the science image header
- print user specified lines from the science image header
- convert and print camera thermal data stored as binary data in the science image header
- display raw images to identify saturated data, cosmic rays hits, and other problems

Spectral Extraction and Basic Reduction:

- reduction of low-dispersion extracted spectra to the form of absolutely calibrated spectrophotometry
- reduction of high-dispersion spectra to the form of calibrated spectra
- customized extraction of low-dispersion spectra from the spatially resolved extracted data using both IUESIPS-type rectangular extraction windows or by fitting gaussians to point source spectra
- correction for camera-sensitivity degradation in low dispersion
- extraction of cross-cuts in the spatially-resolved data
- correction for interstellar extinction using any of a number of galactic, LMC, and SMC extinction curves

Data Manipulation:

- smoothing using boxcar, triangle, or user-specified symmetric filters
- resampling spectra onto uniformly-spaced wavelength scales
- resampling entire high-dispersion spectra to 0.25 Å or coarser resolution
- interpolation of spectra onto common wavelength scales

- co-addition of spectra
- binning data into user-specified wavelength bins
- splicing spectra together

Data Fitting:

- continuum normalization and continuum fitting
- least-squares polynomial fits
- spline interpolation, smoothing, and fitting
- gaussian fitting of spectral lines

A *Data Measurement:*

- equivalent widths or integrated fluxes
- radial velocities
- velocity shifts via cross-correlation
- derivation of interstellar column densities using curve of growth
- fitting observations of early-type stellar winds to theoretical profiles

Reference Data:

- on-line low-dispersion spectral-standard stars and representative astronomical objects
- on-line binned flux catalog for low-dispersion IUE spectra
- Kurucz model atmospheres
- black-body spectra
- spectral line libraries (Kelly and Palumbo (1973), Kelly (1979), and Castor and Lamers (1979)), stellar winds profiles

Plotting:

- interactive-graphics display
- graphics hardcopy
- publication-quality plots using laser printers

Data Reformatting:

- internal formats to ASCII
- internal formats to FITS

More information on the RDAF software, hardware, and databases can be found in the RDAF Tuttorial.

6.2 *Scheduling Use of the RDAFs*

Visits to the GSFC RDAF may be scheduled by calling the GSFC RDAF manager, Randy Thompson, or any other RDAF staff member at (301)-286-8800 during normal business hours, or by sending electronic mail messages to the SPAN address IUE::STAFF. Visits to the CURDAF may be scheduled by calling the CURDAF 303)-492-4054, or by sending electronic mail messages to the SPAN address CYGNUS::BRUGEL. When you call to schedule a visit it is helpful if you know how long you need to use the facility, the IUE program ID (if applicable), and the spectra you are interested in analyzing. There are no charges for using either RDAF. You should be prepared, however, to make your own arrangements for travel and accommodations.

The RDAFs can provide archival researchers with releasable IUE images only. The proprietary period for IUE data is about 7 months from the time of observation. In general, you will not be able to get data which is still proprietary EVEN IF YOU ARE THE PRINCIPAL INVESTIGATOR. If you plan to work on data from a current observing program, you should be prepared to send, mail or carry your Guest Observer tapes to the appropriate RDAF in time for your visit, or have them held at the IUE Observatory (GSFC RDAF only). If you are a co-investigator on a current observing program, you should ask the P.I. to send you the data, ship it to the RDAF for you, or arrange with the IUE Project to have the data sent to you, sent to the CURDAF, or held at GSFC.

Entry to GSFC is restricted to those having the proper badges. IUE Guest Observers may use their IUE badges when visiting the RDAF. Archival researchers and visitors who do not have badges should tell the RDAF staff members when scheduling their visit. You will need to give your institution, citizenship, and the duration of your visit. Processing badge requests by the GSFC security office can take a few weeks, especially for non-U.S. citizens. Please try to schedule your visit at least two weeks in advance if you or any students or colleagues are not U.S. citizens. Visits to the CURDAF do not require badges.

Experienced users of either RDAF who are able to complete their analysis with little or no help from the facility assistants, other than data loading, may want to consider using the facilities remotely. Astronomers with access to SPAN may log on to their RDAF accounts via the network. NSFNET or INTERNET users may access the CURDAF using the TCP/IP protocol. This access method will be available to GSFC RDAF users early in 1989. Remote users of either facility are expected to be sufficiently experienced that they can work with little or no assistance from the staff. At least one visit to one of the RDAFs is required before you may be scheduled as a remote user. The GSFC RDAF has two lines for remote users calling in over commercial telephone lines. The CU RDAF has one line for remote users. RDAF users interested in using the GSFC RDAF remotely should contact Randy Thompson. RDAF users interested in using the CURDAF remotely should contact Ed Brugel.

6.3 *Getting to the GSFC RDAF*

The GSFC RDAF is located on the ground floor of Building 21 at Goddard Space Flight Center. Visitors unfamiliar with the layout of the IUE area (rooms G45-G69) should talk to the secretary outside of Room G61.

GSFC can be most easily reached from Baltimore-Washington International Airport but also from Dulles International Airport and Washington National Airport. Rental car facilities are located at each of the area airports. From Dulles, the simplest approach is to take the Dulles Access Road to I-495 and then go North into Maryland. Continue on I-495 after it becomes I-95 to Richmond. Exit at the Kenilworth Avenue-Greenbelt Road exit and go South. Turn left (East) from Kenilworth Avenue onto Greenbelt Road and continue until you see the sign for the GSFC Main Gate. If you miss the Kennilworth Avenue Exit, proceed to the Baltimore-Washington Parkway and take the exit toward Baltimore. You will exit from the Parkway almost immediately onto Greenbelt Road. Proceed East (right turn from the exit) to the GSFC Main Gate. From National Airport, the simplest (but rather long) approach for those unfamiliar with Washington is to take the George Washington Parkway west to I-495 and then follow I-495 into Maryland (same route as from Dulles). From BWI, turn left from the airport access road onto the Baltimore-Washington Parkway (south). Continue south past the GSFC Visitor's Center and GSFC employees' exits and get off at Greenbelt Road. Two left turns are necessary to get you on Greenbelt Road heading toward GSFC, which is about two miles east.

GSFC can also be reached by a combination of trains and busses from the three area airports as well as from AMTRAK. From Dulles, the simplest approach is to take the bus to National Airport. From National, go to the National Airport METRO station (the local subway system). From the National METRO station, proceed to METRO CENTER station, change from the Blue line to the Orange line going toward New Carrollton. New Carrollton is the end of the Orange line. New Carrollton is also an AMTRAK station. The New Carrollton METRO/AMTRAK station has bus service to GSFC via the T16 line. Service to GSFC begins at 5:45 a.m., and runs every half hour until 8:45 a.m. when service drops to once an hour until 8:15 p.m. The bus will drop you at the GSFC Main Gate, and you will need to walk over to Building 21 from there (approximately a 5 minute walk). From BWI, GSFC can be reached by taking the limousine service to the Greenbelt terminal and the T16 bus line to GSFC.

The motels nearest GSFC are several miles from the facility. Sidewalks are not a strong feature of Maryland highway design, so walking can be at best challenging, and at worst hazardous. Renting a car is probably the simplest way to get to GSFC, your hotel, and to restaurants.

Rates are approximate and include a government discount. All prices are the going rate as of March 1989 and are subject to a 10 percent tax. Ask for a discount for people coming to GSFC. Reservations will be held until 4:00 p.m. ONLY if you give the motel your credit card number. See attached map for general locations.

6.4 *Getting to the CURDAF*

The University of Colorado RDAF is located in Room C-324 of the Duane Physics Building. The nearest visitor parking is located near the University Memorial Center (see the map of the CU Campus). Many of the motels listed below are a short walk from the CU Campus, as are a number of restaurants.

The nearest commercial airport to Boulder is Denver Stapleton International Airport, which is served by numerous national and regional airlines. Commercial bus service is available from Stapleton Airport to Boulder. The service operates seven days a week with 13 daily departures from 8:00 a.m. to 12:20 a.m. the next morning. The present fare is $1.75. This service operates from the airport bus area outside the baggage claim area, via the bus terminal in downtown Denver to Boulder. No changing buses is required. There is also a private limousine service, the Boulder Airporter, which leaves Stapleton Airport every hour from 9:00 a.m. to 9:00 p.m. on Sundays through Fridays, and every two hours on Saturdays (last run at 7:00 P.M.). The fare is $8.50. The limousine will drop you off at the University Memorial Center or at motels on request. Taxi service is also available from Stapleton Airport; the fare to Boulder is likely to be about $40.00. Rental cars can be obtained at the Airport and are particularly nice if you plan to do any sightseeing in the mountains while in Boulder.

AMTRAK service is available to Denver. Long distance busses operate to a central bus terminal also in Denver. Commercial bus service to Boulder can be obtained from the bus terminal in downtown Denver.

Boulder can be reached by automobile on U.S. 36 via the Boulder turn-off from Interstate 25 (I-25) northbound from Denver.

GSFC AREA MOTELS

1 Econo Lodge
9113 Baltimore Blvd.
College Park, MD 20740
(301) 345-4900
$ 43.00 single
or $ 52.20 double
East side of US 1, North of Hwy 193.

2 Best Western Maryland Inn
(Formerly Interstate Inn)
8601 Baltimore Blvd.
College Park, MD 20740
(301) 474-2800
$ 55.80 single
$ 60.30 double
US 1, South of Hwy 193.

3 Ramada Inn
5910 Princess Garden Pkwy.
Lanham, MD 20706
(301) 459-1000
$ 58.00 single
or $ 64.00 double

4 Red Roof Inn
9050 Lanham-Severn Rd.
Lanham, MD 20706
(301) 731-8830
$ 42.95 single
$ 48.95 double

5 Quality Inn
7200 Baltimore Av.
College Park, MD 20740
(301) 864-5820
$ 43.00 single
$ 54.00 double
Northwest corner of US 1
and Beltway exit

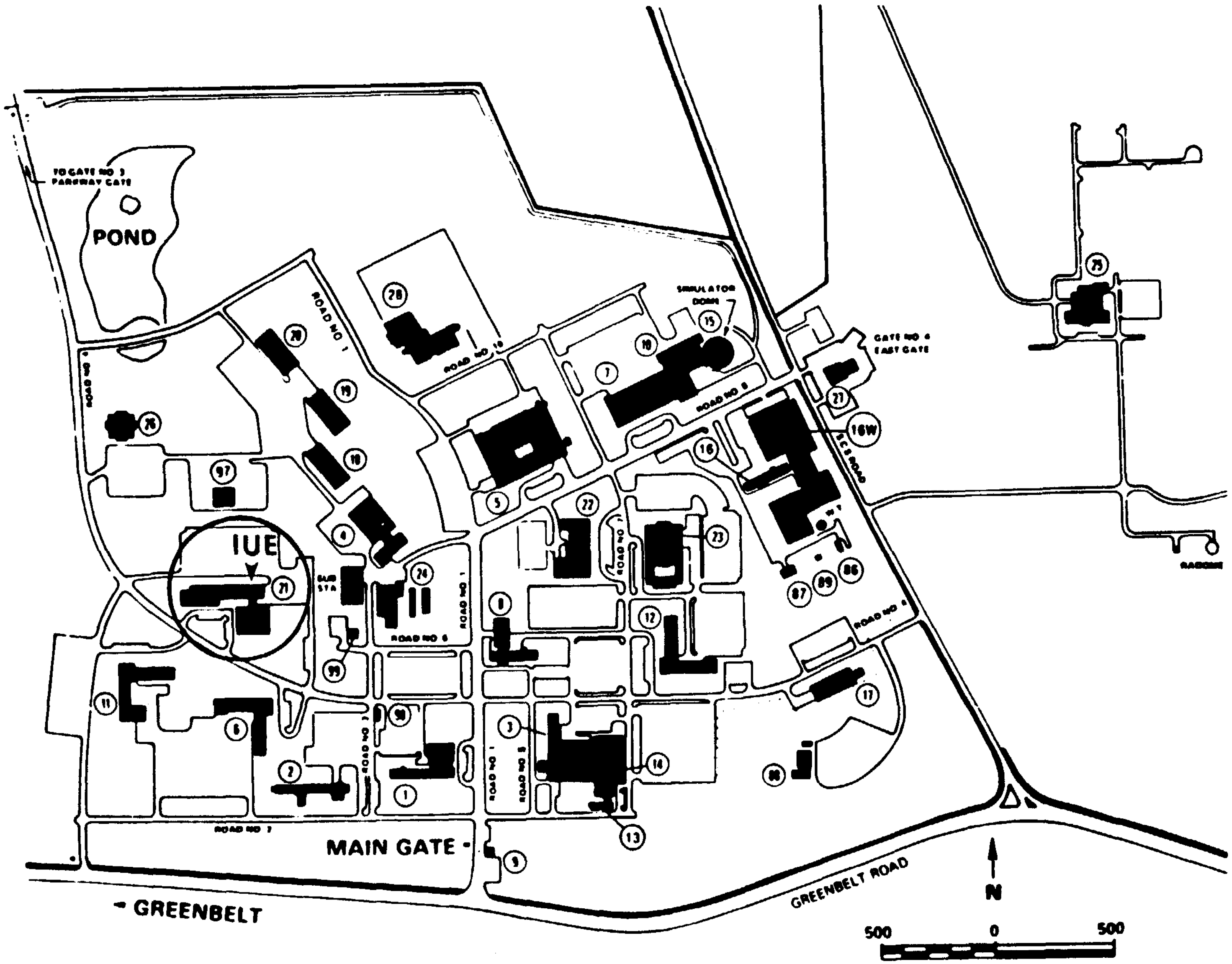
6 Howard Johnson's Plaza
8500 Annapolis Rd.
New Carrollton, MD 20784
(301) 459-6700
$ 68.00 single
or$ 76.00 double
Southwest corner of Hwy 450
and Beltway exit.

7 Holiday Inn
7200 Hanover Dr.
Greenbelt, MD 20770
(301) 982-7000
$ 62.00 single
$ 68.00 double
Behind Shopping center
and BW Parkway

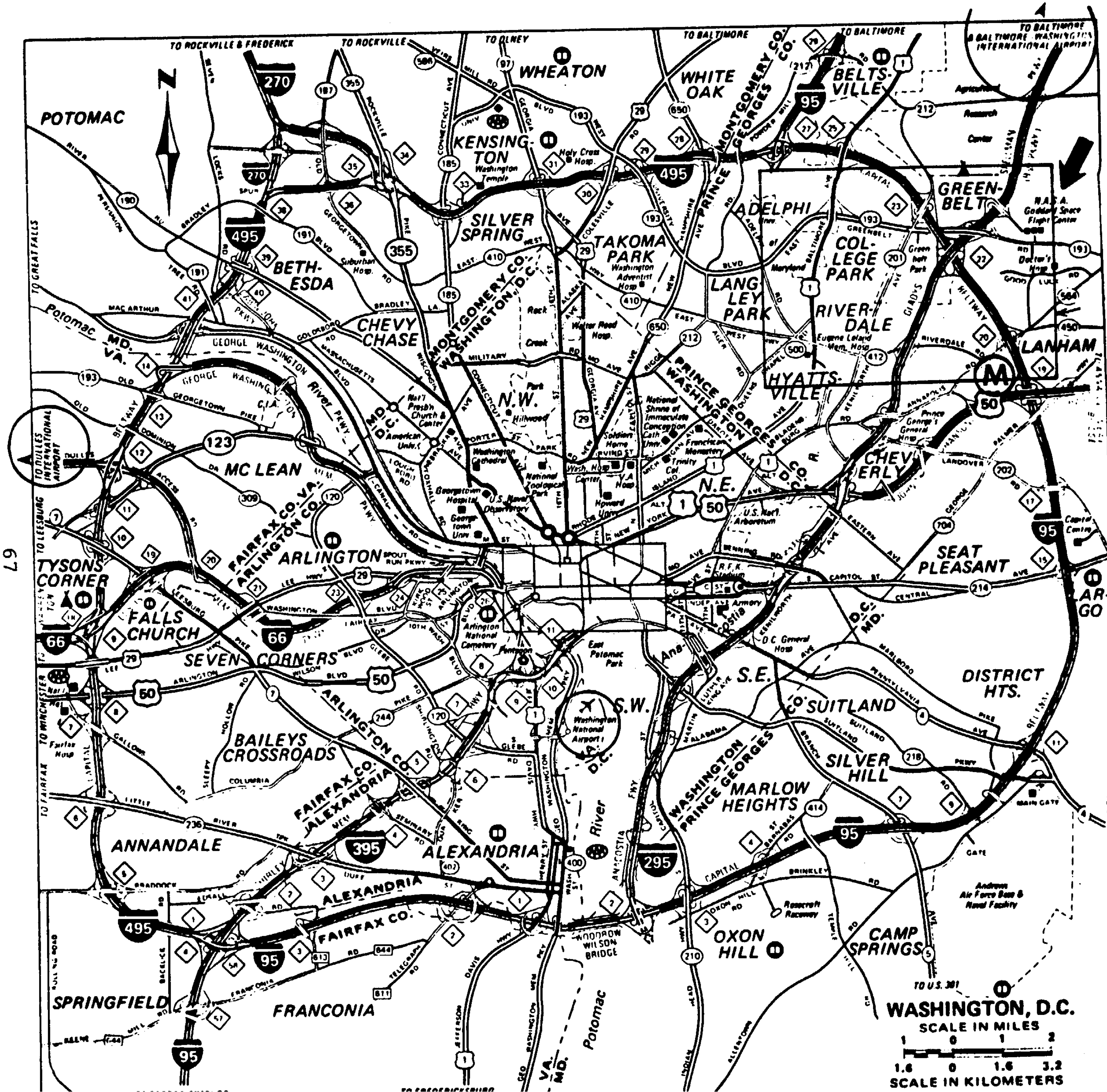
8 Comfort Inn
9020 Baltimore Blvd.
College Park, MD 20740
(301) 441-8110
$ 49.00 single or double

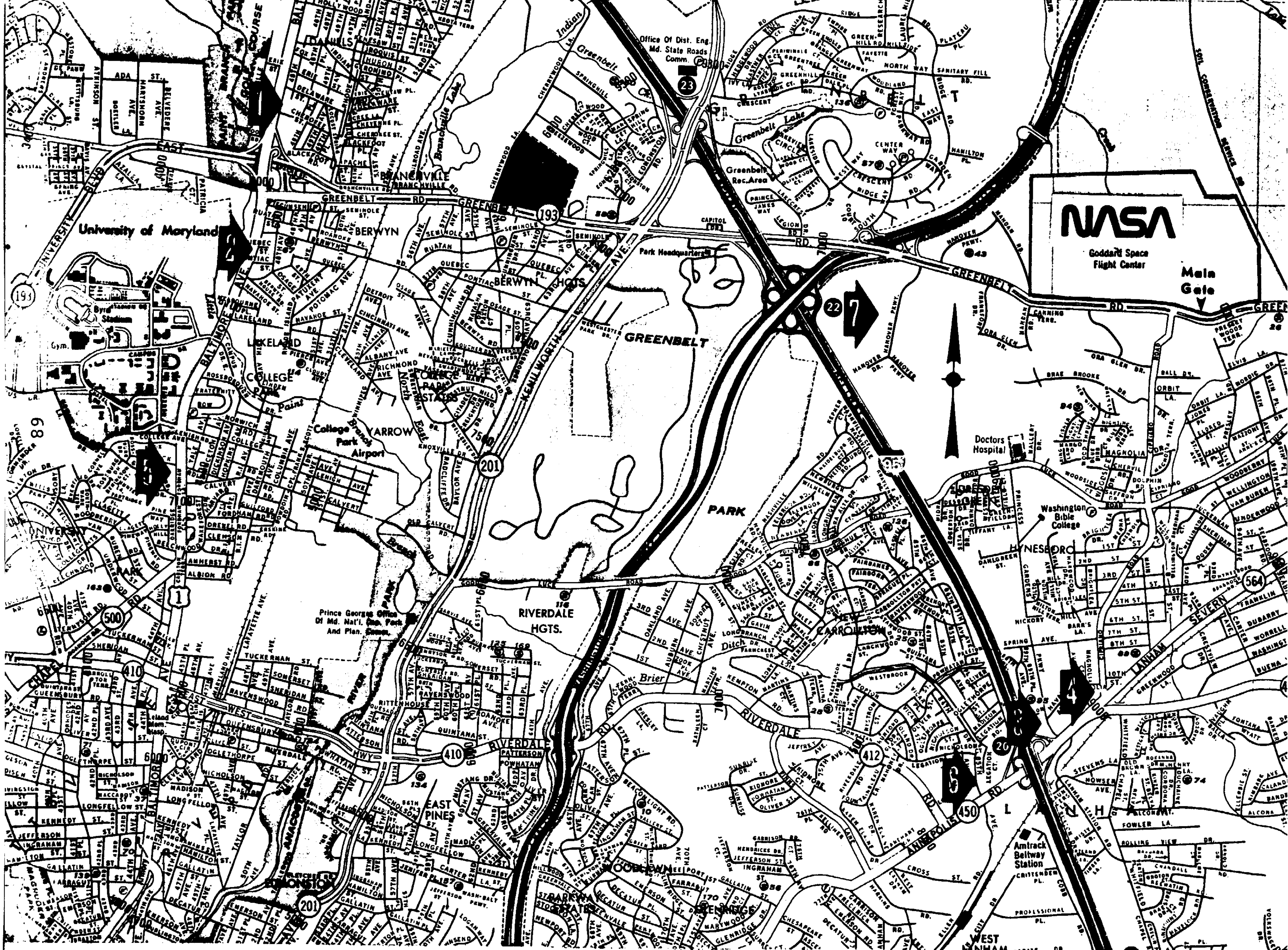
9 Greenbelt Marriott
6400 Ivy Lane
Greenbelt, MD 20770
(301) 441-3700
$ 79.00 single
$ 94.00 double

GODDARD SPACE FLIGHT CENTER
LOCATION MAP



MAIN GATE OPEN 24 HOURS • 7 DAYS A WEEK


WASHINGTON, D.C.
SCALE IN MILES
1 0 1 2
1.6 0 1.6 3.2
SCALE IN KILOMETERS
TO ROCKVILLE & FREDERICK
TO ROCKVILLE
TO OLNEY
TO BALTIMORE
TO BALTIMORE & BALTIMORE-WASHINGTON INTERNATIONAL AIRPORT
TO DULLES INTERNATIONAL AIRPORT
TO GREAT FALLS
TO LEESBURG
TO WINCHESTER
TO FAIRFAX
TO U.S. 301
POTOMAC
WHEATON
KENSINGTON
WHITE OAK
BELTSVILLE
SILVER SPRING
TAKOMA PARK
ADELPHI
COLLEGE PARK
GREENBELT
BETHESDA
CHEVY CHASE
LANGLEY PARK
RIVERDALE
HYATTSVILLE
LANHAM
N.W.
N.E.
S.E.
S.W.
MC LEAN
ARLINGTON
TYSONS CORNER
FALLS CHURCH
SEVEN CORNERS
CHEVERLY
SEAT PLEASANT
LARGO
DISTRICT HTS.
SUITLAND
SILVER HILL
MARLOW HEIGHTS
BAILEYS CROSSROADS
ANNANDALE
ALEXANDRIA
OXON HILL
CAMP SPRINGS
SPRINGFIELD
FRANCONIA
MONTGOMERY CO.
PRINCE GEORGES
WASHINGTON, D.C.
FAIRFAX CO. VA.
ARLINGTON CO.
ALEXANDRIA
FAIRFAX CO.
WOODROW WILSON BRIDGE
Potomac River
Washington National Airport
Andrews Air Force Base & Naval Facility
N.A.S.A. Goddard Space Flight Center
Agricultural Research Center
Rosecroft Raceway
Arlington National Cemetery
U.S. Nat'l Arboretum
R.F.K. Stadium


NASA
Goddard Space Flight Center
Main Gate
University of Maryland
Byrd Stadium
Gym.
GREENBELT
PARK
Greenbelt Lake
Greenbelt Rec. Area
Park Headquarters
Office Of Dist. Eng. Md. State Roads Comm.
BERWYN
BERWYN HGTS.
BRANCHVILLE
LAKELAND
COLLEGE PARK
COLLEGE PARK ESTATES
YARROW
College Park Airport
RIVERDALE HGTS.
Prince Georges Office Of Md. Nat'l. Cap. Park And Plan. Comm.
NEW CARROLLTON
HYNESBORO
Doctors Hospital
Washington Bible College
EAST PINES
EDMONSTON
WOODLAWN
Amtrack Beltway Station
GREENBELT RD.
KENILWORTH AVE.
BALTIMORE AVE.
RIVERDALE RD.
ANNAPOLIS RD.
LANHAM SEVERN RD.
LUSTINE RD.
EAST WEST HWY.
UNIVERSITY BLVD.
193
201
410
412
450
500
564
1

HOTELS NEAR THE CURDAF

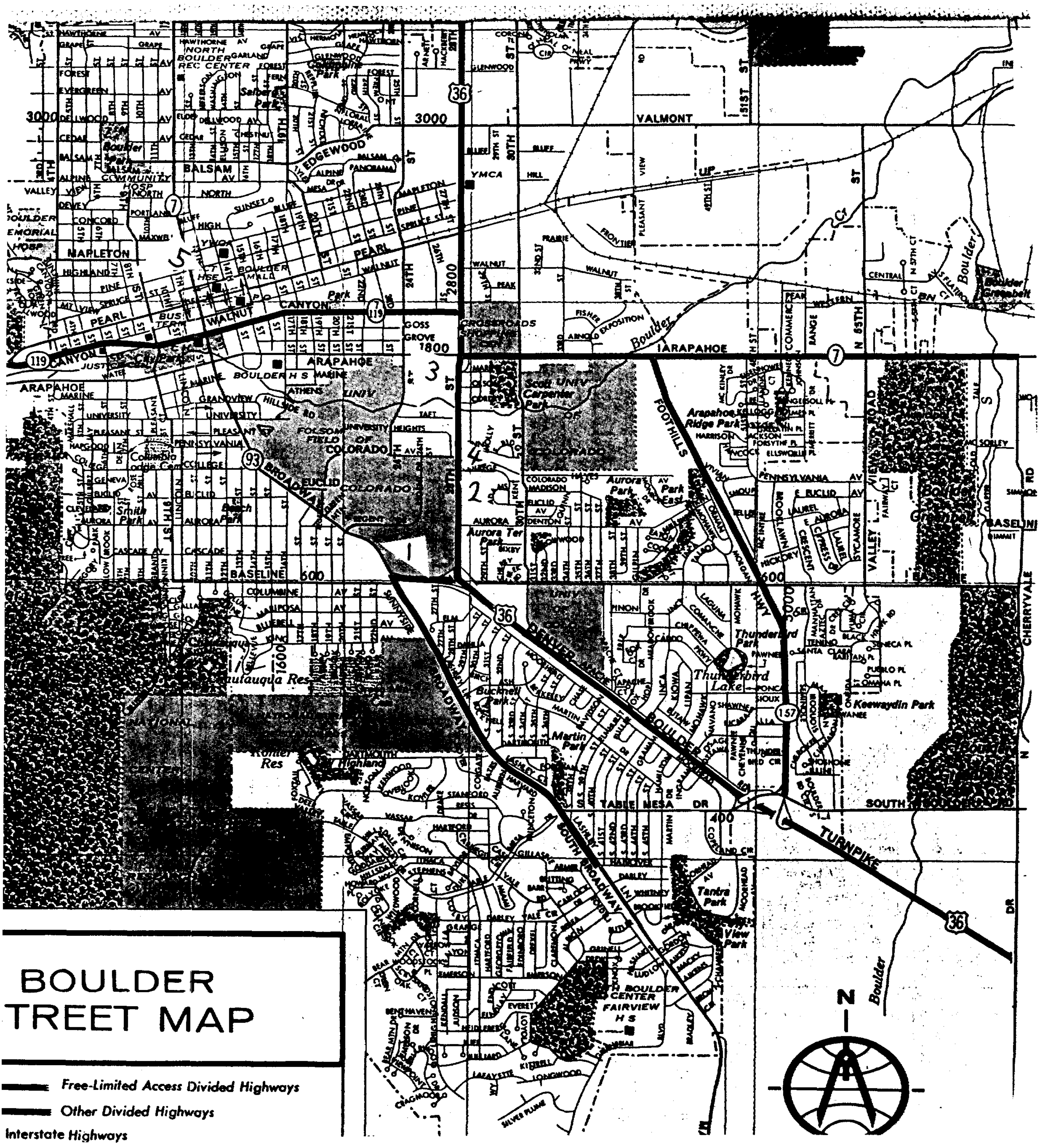
1 University Club
(located on campus)
770 28th St.
Boulder, CO 80303
(303) 449-3800
($ 30 single; $ 40 double)

2 Highlander Inn
(located across from campus)
970 28th St.
Boulder, CO 80302
(303) 447-7800
($34.95 single; $38.95 double)
(rates increase during summer months)

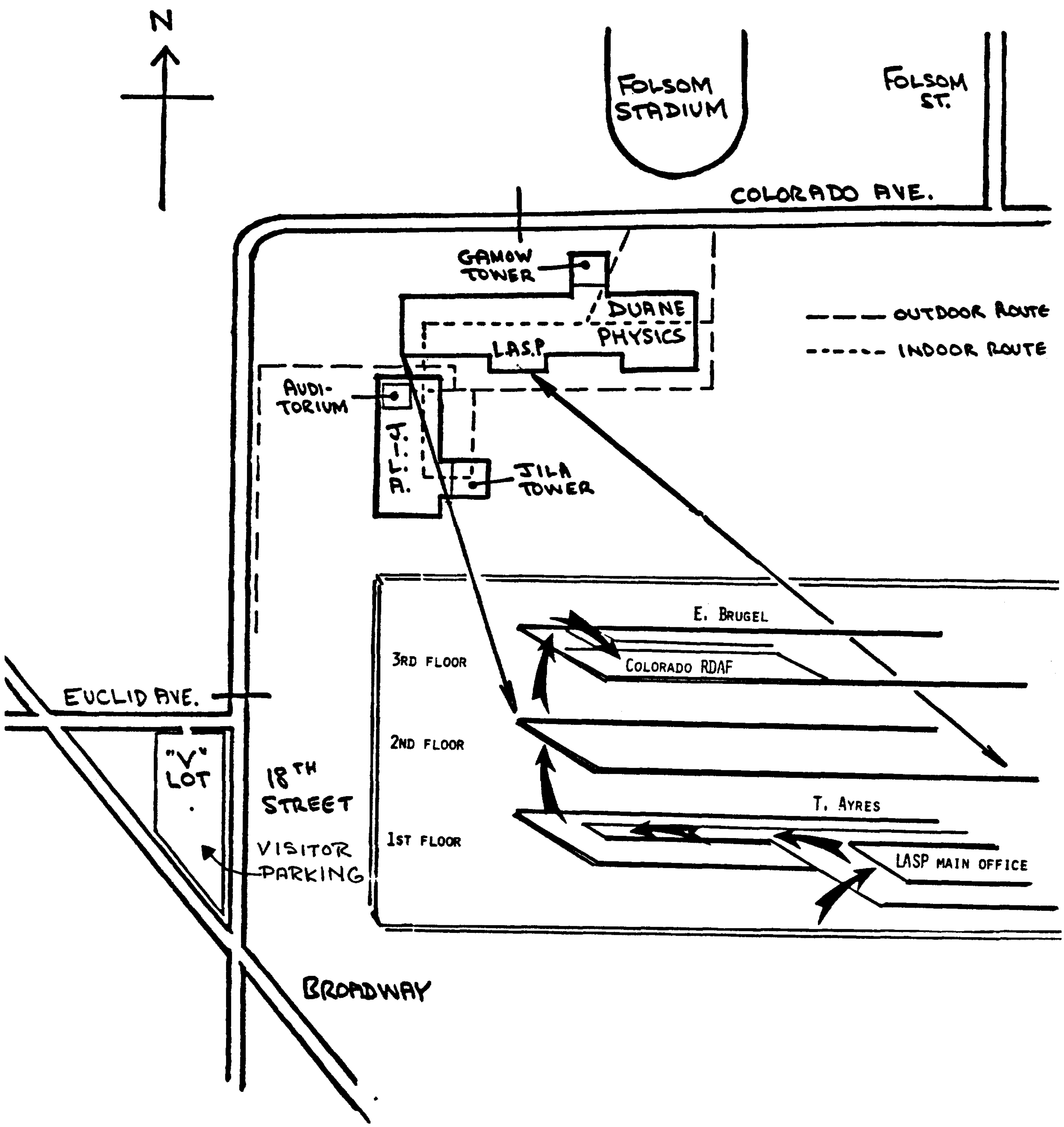
3 Clarion Harvest House
(located across from campus)
1345 28th St.
Boulder, CO 80302
(303) 443-3850
($ 75 single or double;
$ 53 single or double;
depends on availability
of government rate)

4 Skyland Motel
(located across from campus)
1100 28th St.
Boulder, CO 80302
(303) 443-2650
($ 36 single; $39 double)

5 Boulderado Hotel
(located downtown Boulder)
2115 13th St.
Boulder, CO 80302
(303) 442-4344
($ 59 single; $ 75 double)



BOULDER
TREET MAP
Free-Limited Access Divided Highways
Other Divided Highways
Interstate Highways
N
VALMONT
ARAPAHOE
BASELINE
TABLE MESA DR
SOUTH BOULDER RD
TURNPIKE
FOOTHILLS HWY
BROADWAY
SOUTH BROADWAY
DENVER
BOULDER
CANYON
PEARL
WALNUT
EDGEWOOD
BALSAM
MAPLETON
COLORADO
EUCLID
AURORA
CASCADE
COLUMBINE
ARAPAHOE
UNIV
COLORADO
FOLSOM FIELD
Scott Carpenter Park
Chautauqua Res
Thunderbird Lake
Thunderbird Park
Keewaydin Park
Martin Park
Bucknell Park
Tantra Park
View Park
Aurora Park
Park East
Arapahoe Ridge Park
Smith Park
Beach Park
Salberg Park
Columbia Cem
Boulder Greenbelt
BOULDER H S
FAIRVIEW H S
BOULDER CENTER
NORTH BOULDER REC CENTER
CROSSROADS SHOPPING
YMCA
COMMUNITY HOSP
BOULDER MEMORIAL HOSP
28TH
30TH
55TH ST
VALLEY VIEW RD
CHERRYVALE
3000
2800
1800
1600
600
400


N
FOLSOM STADIUM
FOLSOM ST.
COLORADO AVE.
GAMOW TOWER
DUANE PHYSICS
L.A.S.P.
OUTDOOR ROUTE
INDOOR ROUTE
AUDI-TORIUM
J. I. L. A.
JILA TOWER
EUCLID AVE.
"V" LOT
18TH STREET
VISITOR PARKING
BROADWAY
E. BRUGEL
3RD FLOOR
COLORADO RDAF
2ND FLOOR
T. AYRES
1ST FLOOR
LASP MAIN OFFICE