Observing with the IUE

In several respects observing with the IUE is similar to using ground based optical telescopes to obtain spectra on photographic plates. All of the activities of the instrument are initiated by real time commands. The telescope is slewed (with errors that we hope are less than 3 arc-min) to the 1950 coordinates of the target. The observer identifies his target by inspection of an 10.8 arc-min square image of the sky in the direction the telescope is pointed. The length of the exposure may be altered in real time but the exposure level cannot be judged without reading out the image. Reading the image permits the observer to see quick-look results as soon as 15 minutes after the exposure is completed. As with developing a photographic plate, however, reading the image prevents any more signal from being added to that spectrum.

There are some aspects of IUE observing that may be unfamiliar to the new user. Van Allen belt radiation may limit the length of the exposures that can be obtained during the second half of the 16 hour NASA operation shift. As seen from the spacecraft the Earth will appear to circle the sky every 24 hours, no doubt covering the desired target at just the wrong time. These problems and others will be discussed further below.

The IUE observer can get the most efficient use of his time if he prepares adequately and is aware of possible pitfalls. We have prepared this report to help the novice (and veteran) IUE observer acquire the information he needs.

1. Pre-visit Preparations

As a planning aid the IUE Observatory provides sky maps which illustrate the sky as viewed from the satellite (Fig. 1). Superimposed on the celestial grid a large circle of S's represents the boundary of the forbidden region about the Sun. A warning zone about the Moon is represented by a small circle of M's. The path followed by the Earth's center is the horizontal solid line in the middle of the map. The GMTs at the top of the map give the time at which the Earth's center appears in the direction directly below. The circles above the GMTs represent the Earth's phase. An envelope of E's represents a warning zone about the Earth. One should plan observations to avoid the Sun and Earth.

Having correct 1950 coordinates and being able to identify the target is essential. Hours have been spent observing the wrong star because of misidentifications. For stars fainter than 6^m, it is advisable that the Guest Observer (GO) bring finding charts. The "finder scope" (Fine Error Sensor) can view a field of up to 16 arc-min in diameter. (A 10.8 arc-min square field is standard.) The resolution of the FES is only 12 arcsec. Finding charts in the form of polaroid prints, slides, transparencies, or hand-drawn charts to an appropriate scale are adequate. (Scales of 6 to 12 arcsec/mm are used by the staff for their own finding charts.) Transparencies or slides are convenient because they can be rotated and flipped to match the orientation of the image produced by the FES. If a target is part of a multiple star system, is diffuse, or has a visual magnitude below 13.5, offsetting from a nearby star may be necessary. This technique is discussed in more detail below.

The IUE does not have an exposure meter so an accurate estimate of the exposure time is necessary. Exposure time can be estimated by $t=E_\lambda/F_\lambda$. E_λ in erg cm^{-2} Å^{-1} is given in the following table:

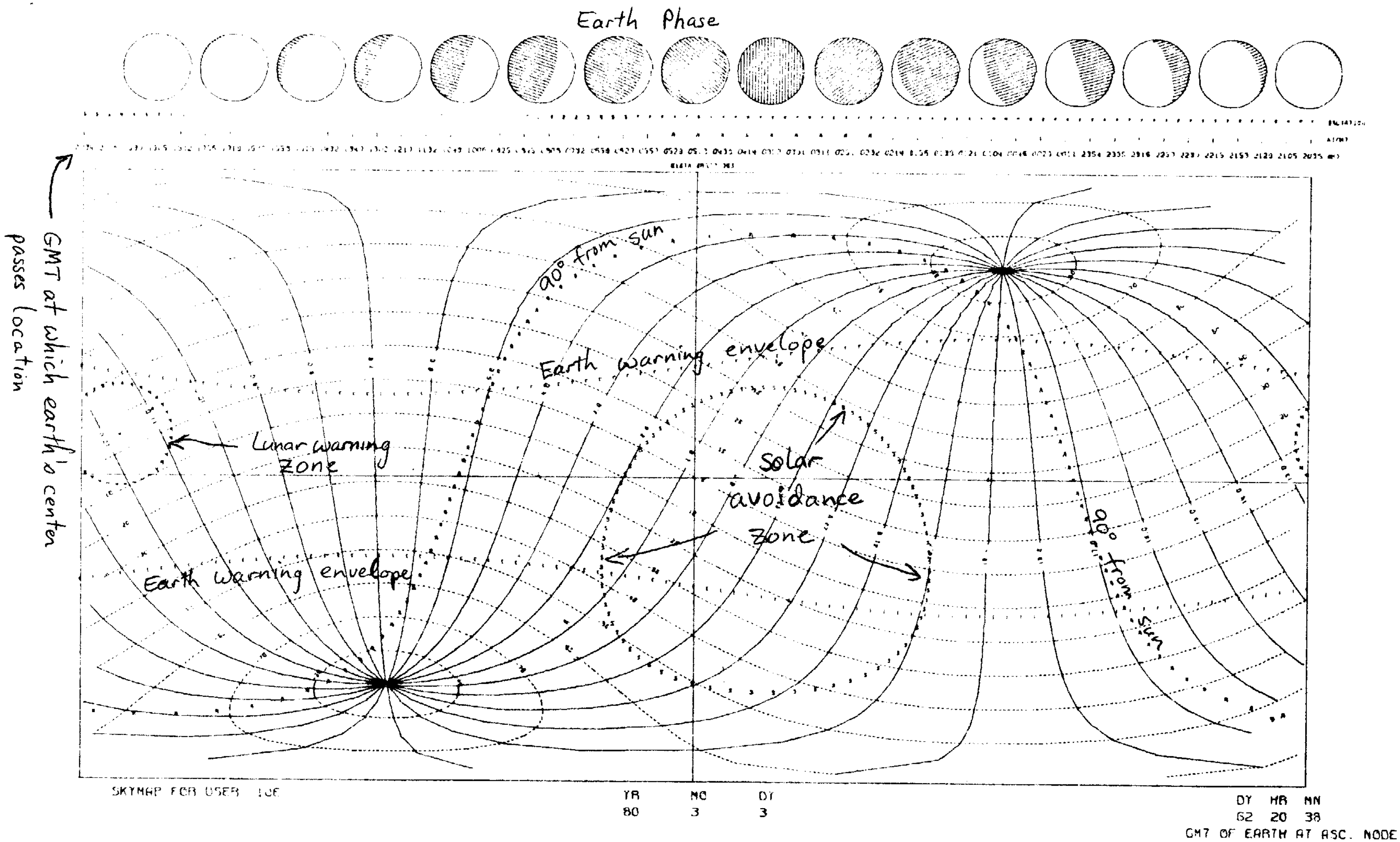

Figure 1. Sample Sky Map

Normally Sky Maps will indicate target Locations with numbers.

	High Dispersion small aperture	Low Dispersion large aperture
1300 Å	1.8×10^{-7}	1.1×10^{-9}
1800 Å	8.3×10^{-8}	5.1×10^{-10}
2700 Å	2.6×10^{-8}	2.0×10^{-10}

Estimates of F_λ in erg cm^{-2} S^{-1} $Å^{-1}$ may be obtained from published results of OAO-2 (e.g. Code and Meade, 1979), Copernicus (e.g. Snow and Jenkins, 1977), TD-1 (e.g. Jamar et. al. 1976 or Thompson et. al., 1978) and ANS satellites.

Clever estimates also may be based on physical models. Be sure to use the interstellar extinction curve (Bless and Savage 1972) when estimating fluxes for reddened stars from those for unreddened stars. Finally, the GO may get a better feeling for the exposure time by looking through the Observatory Log and by talking to the Resident Astronomers after arriving at the Observatory.

The values of E_λ given above are based on the stellar flux calibration used by OAO-2 Copernicus. TD1 and ANS fluxes are based on different calibrations. Use the multiplicative factors in the table below to convert TD1 and ANS fluxes.

	TD1	ANS
1380 Å	1.35	----
1550 Å	1.37	1.35
1800 Å	1.15	1.14
2200 Å	1.02	0.93
2500 Å	1.13	1.02
2700 Å	1.32	----
3300 Å	----	1.09

The value of E_λ given above are chosen to give a peak camera response of about 200 Data Numbers (DN). In some parts of the images higher intensities will be less accurately processed because they exceed the highest level of the intensity transfer function. The table below gives an estimate of the DN of the highest unsaturated intensity transfer function level as a function of wavelength for low dispersion spectra.

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

Unreddened stars with types B3 and earlier will produce maximum camera response at 1300 Å and 2700 Å in the two spectral ranges. Cooler and reddened stars will produce maximum camera response at 1800-1900 Å and 2800-3000 Å. The continuum around 1500 Å and 2200 Å will be less heavily exposed regardless of stellar type. Moreover, the intensity decreases toward the ends of each order in the echelle (high dispersion) mode. Hence, to obtain well exposed spectra of a feature near the end of an order (for example, Mg II λ2803) it may be necessary to overexpose much of the rest of the image. The telescope operations staff should be informed prior to the start of any intentionally overexposed spectrum because too high an overexposure level may be hazardous to the camera.

Observers may request to add a small number of new targets to their program by writing to the Project Scientist with target names, 1950 coordinates, and a statement justifying the additions. These requests may be submitted after arriving at the Observatory, but several days should be allowed for approval.

Observers are expected to arrive at the Observatory at least one day prior to their first observation for orientation and for consultation with the Resident Astronomers regarding their observations.

2. At the Observatory

The GO's role is to specify the observations he wants (by target with accurate 1950 coordinates, instrumental modes, and exposure time), to identify the target, and to revise his observing plan as warranted by his analysis of the quick-look data available to him. An experienced IUE staff of Telescope Operators (TO) and Resident Astronomers will control the instrument and will attempt to maximize efficiency given the scientific requirements. The GO specifies his desired observations via an "observing script" (Fig. 2) which must be completed above the horizontal line before the TO can begin to obtain the spectrum. The TO should be warned if any part of the spectrum will be overexposed and if a target will be difficult to identify. To help keep his observing efficient it is recommended that the GO tell the TO of his plans and options as far in advance as possible.

After the exposure is complete and the image transmitted to the control center, it is displayed to the GO with intensity levels being color coded. A judgement of whether the spectrum shows the features desired can usually be made from these two-dimensional displays. In addition, the TO will generate quick-look intensity plots and histograms which show the relative frequency of exposure levels in the spectrum (Fig. 3).

Some aspects of IUE observing with which the new Guest Observer may not be familiar are described here.

(a) Maneuvers. Unlike at most ground-based observatories, the telescope can be slewed only along one axis at a time. Normal slew rates are in the range of 4° to 6° per minute. An additional constraint that does not exist at ground-based observatories is that the solar paddles must remain facing the sun to within fairly strict limits. Because of this last constraint the telescope may have to be slewed a much longer distance than the GO would expect from the great circle distance between his targets. For example, to maneuver between two targets near the antisun it may be necessary to slew 360° even though the shortest distance between them is less than a degree.

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

OBSERVER *A. Holm & C. Wu*

PROGRAM ID *RCCAH*

OBJECT *R CrB*

YEAR *1980*

RA (1950) *$15^h 46^m 30.69$*

TARGET SERIAL # *4*

DEC (1950) *$+28° 18' 32.2$*

m_V *5.8* Sp. T. *F8 Ibp* E(B-V) ____

(B-V) ____ Class No. *52* ← *Class is defined in the manual on Pre-observation planning received with your acceptance letter.*

CAMERA: **(Long)** Short

PREP: **(Standard)** Overexposed Fast None

Dispersion Mode: High **(Low)**

Large Aperture: Close **(Open)**

Object Aperture: **(Small)** *+* **(Large)**

EXP Time: ___ min *60* sec *large*; *300 sec small*

PROCESSING SPECIFICATIONS

*** NO DEFAULTS ***

DO NOT PROCESS ____
EXTENDED SOURCE REDUCTION ____
POINT SOURCE REDUCTION *X*
PROCESS BOTH APERTURES *X*
CONTINUUM WEAK ____
USE SPECIAL CALIBRATION ____
(IMAGE NO. ____

EXP Gain: **(Max)** Med Min

READ Gain: **(Low)** High NO READ

Remarks: *PREPs other than "STANDARD", EXP Gains other than "MAX", and READ Gains other than "LOW" are not calibrated and are for special purposes only.*

This section will be completed by the TO as he obtains the observation.

RA/TO Observatory Record Number ____

FES Counts: **(Out)** In Overlap Underlap

Tracking: Gyro FES Fast Slow

Can be used to derive a visual magnitude

Focus: Radiation Beta S/C ROLL FSS Roll

EXP Start GMT: Day ___ Hr ___ Min ___ **(THDA IN EXP = ____)**

READ Start GMT: Day ___ Hr ___ Min ___ *Camera temperature*

Archive Tape ____ **(Image Sequence # ____)**

EMISSION LINE = ____ DN, or ____ X OVER.

CONTINUUM = ____ DN, or ____ X OVER.

BACKGROUND = ____ DN, or ____ X OVER.

NOISE: *The number assigned here will be used to identify the output products related to this observation.*

Comments *Figure 2a. A typical observing script for a double exposure with the Long wavelength spectrograph in the Low dispersion mode.*

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

OBSERVER F. H. Schiffer

PROGRAM ID PHCAL

OBJECT η UMa

YEAR 1979

RA (1950) $13^h 45^m 34.3^s$

TARGET SERIAL # 24

DEC (1950) +49° 33′ 44″

m_V 1.84 Sp. T. B3 V E(B-V) +0.02

(B-V) ____ Class No. 21

CAMERA (Long) Short

PREP (Standard) (Overexposed) Fast None

Dispersion Mode (High) Low

Large Aperture Close (Open)

Object Aperture (Small) Large

EXP Time __ min 9 sec

PROCESSING SPECIFICATIONS
*** NO DEFAULTS ***
DO NOT PROCESS ____
EXTENDED SOURCE REDUCTION ____
POINT SOURCE REDUCTION X
PROCESS BOTH APERTURES ____
CONTINUUM WEAK ____
USE SPECIAL CALIBRATION ____
(IMAGE NO. ____

EXP Gain (Max) Med Min

READ Gain (Low) High NO READ

Remarks: Standard star observation for sensitivity monitoring. Overexposed PREP is used to remove residual from previous saturated spectrum.

RA/TO Schiffer/Ehlers

Observatory Record Number 5564

FES Counts Out 5008 In 2019 Overlap (Underlap)

Tracking (Gyro) FES (Fast) Slow

S/C ROLL 127° 18′ 35″

Focus −2.4 Radiation 0.8 Beta 56° 48′ 18.″1 FSS Roll +0° 0′ 41.8

EXP Start GMT Day 96 Hr 23 Min 17:58 THDA IN EXP = 10.2

READ Start GMT Day 96 Hr 23 Min 58

Archive Tape # 986

Image Sequence # LWR 4202

EMISSION LINE = NA DN, or ____ X OVER.

CONTINUUM = 200 DN, or ____ X OVER.

BACKGROUND = 30 DN, or ____ X OVER.

NOISE: $DN_{MAX} = 51$ from $y = 355$ to $y = 345$

Comments Figure 2b. A typical Completed Observing script for a high dispersion spectrum covering the 1845 Å to 3230 Å region.

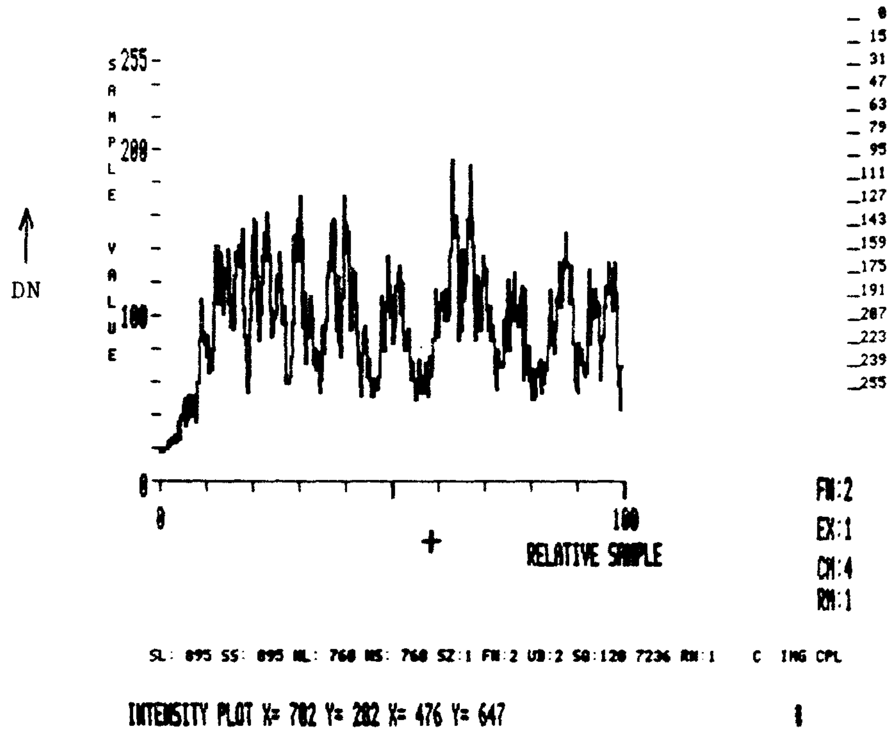

Fig.3a- Intensity plot along high dispersion order shows spectral features but may contain systematic errors because of averaging of pixels and geometrical distortions in image.

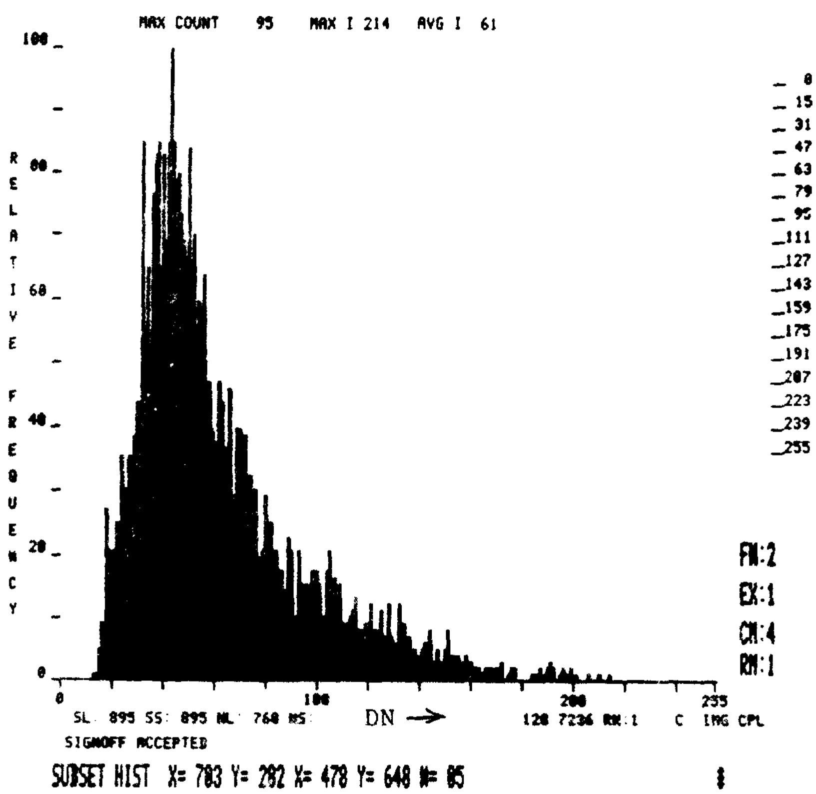

Fig.3b- Subset histogram along same high dispersion order shows relative frequency of pixels with given DN values. Peak intensities and average background can be determined for the order from this display.

Maneuvers normally require 1 to 5 minutes to prepare. Following a maneuver, it normally takes about 10 minutes to identify the target, maneuver an aperture to it, and start the exposure.

(b) Particle Radiation. During US2 operations shift (the second 8 hour shift) the IUE passes through the radiation belts. The particle radiation increases the background level on the cameras and usually limits the length of exposures that can be obtained. The intensity of the particle radiation varies with solar activity. A survey of the peak radiation levels during the first 100 days of 1979 and the first 100 days after launch in 1978 is given in the table below. The radiation level is described in terms of Data Numbers (DN)/hour where the Data Number is the unit of intensity in the telemetered camera data. A DN of 205 is regarded as the optimum exposure and the telemetry cannot handle any DN exceeding 255.

Peak Radiation Level		Percentage of Days Affected		Radiation Monitor Reading
(DN/hour)	%saturation/hour	1979	1978	
≤ 20	≤ 8 %	20 %	7 %	< 1.0
20-40	8-16	34	11	1.0-1.5
40-100	16-40	26	23	1.5-2.0
100-300	40-120	10	27	2.0-2.5
≥ 300	≥ 120	10	33	> 2.5

There is a radiation monitor in the IUE which permits GO's to modify exposure times as necessary to avoid excessive background.

(c) The Acquisition Camera. For target identification the Fine Error Sensor (FES) raster scans a 10.8 arc-min square field once to build up an image of the star field at the end of the maneuver. A limiting magnitude of 12.0 can be reached with a 48 second raster scan. The identification of fainter stars requires appropriately longer integrations. The sky brightness is about 16th mag but will be increased when viewing near the Earth, for example, to 14th mag at 50° from the Earth (Schiffer 1979). After the target is identified the FES is commanded to track mode on the target to measure its position to the precision necessary to place its light in the 3 arcsec aperture. Targets as faint as 14.5 can be tracked in this mode.

In the track mode the FES counts can give an estimate of the visual magnitude of the target. Holm and Crabb (1979) found

$$V = -2.5 \log \left[\frac{C}{1-1.6E-4 \ C^{0.781}} \right] -0.24(B-V) + K$$

where

$$K = \begin{cases} 16.59 & \text{in overlap made} \\ 11.10 & \text{in underlap mode} \end{cases}$$

and

$$C = \begin{cases} \text{FES counts} & \text{in fast track} \\ \text{FES counts}/4 & \text{in slow track} \end{cases}$$

This relationship is good to 0.1 magnitude for V between 0 and 12 and for B-V $\leq$ 0.9.

Finally, after the appropriate aperture has been moved to the target the FES is used to hold the spacecraft steady by guiding on a field star.

(d) Camera Operations. Reading an image from a camera requires that over 600,000 numbers be transmitted to the control center. After the image has been read, it must be re-prepared ("PREP"ed) to erase residual images and to place a reproducible pedestal on the target. A PREP involves at least 2 lamp exposures and 2 reads of the camera. A read followed by a standard PREP requires about 23 minutes just for the camera operations. Target acquisition cannot be carried out during this time because the camera work uses all the telemetry.

Some of this camera overhead time can be concealed by carrying out two operations simultaneous. Reading and preping one camera while exposing the other is routine, as is preping while maneuvering.

(e) Some Potential Problem Areas. There are several potential problems that can degrade the quality of the data, lose observing time, or prevent the desired target from being observed.

Periodic microphonic noise is seen frequently on both SWP and LWR images. In SWP images it is usually less than 4 DN and covers a large area of the image. In the LWR images it may have peak intensities of 50 DN or more and it usually is confined to a narrow band in the lower part of the image. This band often occurs in the vicinity of the Mg II λ2800 doublet in high dispersion. The LWR microphonic band can be made to appear at a different location in the image by lowering the telemetry rate with an increase in the amount of time required for camera operations.

Hardware and software errors can occur in the computers used to control the IUE. These errors stop the computer. With the mildest problems the computer is restarted within a minute. In the worst situation the error occurs while an image is being read and all the data are permanently lost.

Occasionally, the on-board computer which controls the automatic functions of the spacecraft is stopped by an error. This "crash" will usually cost 3 hours or more of observing time while the attitude of the spacecraft is determined.

The receiving antennas also are controlled by computers which occasionally malfunction. The worst time for this to occur is when an image is being read because the data will be permanently lost.

The on-board computer normally operates with a temperature in the vicinity of 50 ^{o}C. Observing targets in the zone between 85^{o} and 125^{o} of the sun may cause the computer to overheat, especially in winter when the Earth is near perihelion. If the computer exceeds the safe operating temperature, the IUE must be slewed to a target outside the hot zone.

Twice a year, in early spring and early fall, the IUE's orbit carries it through the Earth's shadow once each day. During the shadow passages, which may be up to 70 minutes long, no observations or maneuvers can be carried out because the batteries lack sufficient capacity.

The IUE's solar arrays are slowly degrading. This degradation eventually will limit the observations that can be made near the anti-sun or in the zone 45^{o} to 55^{o} from the Sun.

(F) Efficiency. As the above sections indicate there is considerable overhead time involved in obtaining any IUE spectra. An average IUE usage is given in the table below.

Activity	Time Used
Exposing	46%
Camera Operations — including operations not concealed in exposures or in maneuvers.	21
Maneuvers — includes preparation as well as actual slew time.	14
Acquisition — includes identifying and locating the target, moving it to an aperture, moving it from aperture to aperture, etc.	15
Non-science overhead — includes radar ranging for orbit determination, switching between commercial and diesel power for thunder storms, switching transmitters, dumping momentum from the reaction wheels, minor software problems, etc.	4
Major losses of time — includes losses of time exceeding $\sim$30 min caused by on-board or ground software and hardware problems.	1

The observer may expect a slight increase in efficiency as we continue to improve the support software system. However, overhead will remain high because most activities must be executed sequentially.

3. Some Special Observing Techniques

a. Widened Spectra - The signal to noise ratio can be improved for low dispersion spectra by widening the spectra. This can be done by trailing the star perpendicular to the dispersion or by taking multiple exposures with the star being offset perpendicular to the dispersion for each. Trailed spectra are most efficient for bright stars. The exposure time is 3.7 times as long as the exposure time of an untrailed spectrum with the same peak exposure level. Multiple exposures are more efficient if the total desired exposure time exceeds 6 to 10 minutes.

b. Offset Observations for Faint Objects - At a telemetry rate of 5×10^3 bits S^{-1}, the limiting magnitude for a star to be detectable by the more sensitive fine error sensor (FES2) is 13.5. For fainter objects, lower telemetry rates will be necessary, but then sampling time for the whole 16' field of view will be long. So for objects between $13^m.5$ and $15^m.5$ (limiting magnitude for the longest sampling time), offset from a neighboring star is needed. The distance from the offset star to the target should be $\leq 0^\circ.5$ and ideally only a few arc-minutes. Before the slew, we center the offset star on a reference point in the FES. If accurate 1950 right ascension and declination for both the target star and the offset star are input to the computer for calculating the offset maneuver, the target star should be at the reference point after the slew. Then to locate the target, a one arcmin-square portion of the sky around the reference point is mapped out with the longest sampling time. From the small postage stamp FES2 map, we can command further small maneuvers until most of the light from the target falls on one FES pixel centered on the reference point. Then we can maneuver the target into the desired aperture by "canned" slews.

If the target is fainter than $15^m.5$, it cannot be seen by FES2 and the offset will have to be done blindly. In this case, the offset star can be put in the large aperture before slewing to the target. After the slew, the target should be in the large aperture. Since the large aperture is only 10" X 20" oval (small aperture is 3" circular), positions accurate to one arc-second or better are necessary for the offset and target stars. Be sure to take the proper motion between 1950 and 1980 of the offset star into account.

c. Moving Targets - Solar system objects, except the outermost planets, are moving sufficiently fast that their motion has to be compensated. Usually it involves the trimming of the gyros to the drift rate of the target to minimize the drift of the telescope with respect to the moving target. During the exposure, the spacecraft pointing is held either by gyros or tracking on the light of the object spilled over the 3" aperture. The earth, the moon, Jupiter, Saturn and Venus are so bright that the fine error sensor is saturated when viewing them. A technique has been developed to use the fine error sensor image of scattered light to put Venus' image in an aperture, but both the Moon and the Earth would have to be observed by blind offset techniques and under gyro control. To observe the moon its parallax as seen from the spacecraft must be taken into account.

Jupiter and Saturn can be observed by offsetting from their satellites if an accurate ephemeris is available. (The Gallilean satellites of Jupiter can easily be tracked to within 2 arcmin of the planet despite the scattered light problem.)

Moving target observers must prepare an ephemeris of target position in 1950 right ascension and declination before arriving at Goddard. An ephemeris should also be prepared for any satellite which will be used for offsetting. Current techniques for observing moving targets make a table of rates in arcsec/hour in right ascension and declination necessary. If offset guiding using a satellite as a guide star is desired, a table giving the distance and change of distance between target and guide object as a function time is desirable. The time interval between entries in this ephemeris depends on the rates involved, the accelerations, and the degree of pointing accuracy your observing program requires. Plan to contact the Resident Astronomers well in advance of your visit to discuss your specific problems.

d. Double and Multiple Star Systems - Close bright companions will confuse the FES and prevent the light from the target from being placed in the aperture. Targets in multiple star systems have been observed by using the blind offset technique discussed above for faint objects. Again, accurate positions for both target and set star are essential.

e. Variable stars - Visual magnitudes accurate to 0.1 mag can be obtained from the FES to aid in estimating exposure time and to assist interpretation.

f. Extended Sources – The FES will normally track the center of light of a source with some central concentration, for example, most globular clusters and most galaxies. Offsets can be generated if the target is not at the center of light. Sources lacking a central concentration have to be observed as blind offsets as described in b. above.

g. Double Exposures - If low dispersion is required, two or more spectra may be obtained on a single image. This is done by exposing consecutively with the target's light passing through the large and small apertures or even passing through different locations in the large aperture. The advantage of this is that the camera overhead time per spectrum is reduced. Thus, the technique is useful for increasing efficiency, for studying objects which vary on a short time scale, or for hedging your bets when there is no accurate way of estimating exposure time. The disadvantage of using the small aperture is that its throughput is only 50 $\pm$ 10% of the large aperture's throughput.

4. Surviving At Goddard

The following information may make your 16-hour observing shift more bearable. A Goddard cafeteria is located in the same building as the IUE Science Operations Center, but it is closed on weekends and holidays. The cafeteria is open between 7:30 and 8:30 a.m. for breakfast and between 11:00 and 1:30 for lunch. To help cover those intervals when the cafeteria is closed, the Observatory has a refrigerator and a microwave oven. Please help keep these units clean.

The air conditioning unit in the telescope operations room helps to provide an illusion of a mountain top observatory, especially in the summer. Bringing a light sweater is recommended.

Smoking is not permitted in the telescope operations room but is permitted in your office and the hallways.

We have access at all hours to a library containing all the major journals and some catalogs. The IAU circulars and most observatory publications are not represented. Moreover, it is not unlikely for the catalog you need, e.g. the variable star catalog, to be signed out and locked in someone's office.

You might consider leaving the phone number of where you are staying with the Resident Astronomers or Telescope Operator so that they may be able to reach you if necessary.

5. Additional References

A more detailed, although preliminary, technical description of the IUE and its in-orbit performance can be found in papers prepared by the commissioning team (1978). Pasachoff et al. (1979) describe a typical observing run with only a few inaccuracies, as does Bohm-Vitense (1979).

For further information IUE Resident Astronomers for operations (Al Holm, Skip Schiffer, and Charlie Wu) can be reached at 301-344-7537. Observatory Director Don West can be called at 301-344-6901. Project Scientist Al Boggess can be called at 301-344-5103.

Al Holm
C.-C. Wu

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