Observing with the IUE

1. Pre-visit Preparations

Preparation for IUE observations is quite similar to that required for using ground based optical telescopes. 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. 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 Fine Error Sensor (FES). Use of the Observatory's automatically produced finder fields is usually slightly slower than of hand held charts. Moreover, at the present, finder fields are only produced for zones covered by the Palomar Sky Survey. A GO planning to use the automatically produced finder fields should verify their accuracy before coming to observe. 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:

	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 in erg cm^{-2} S^{-1} $Å^{-1}$ may be obtained from published results of OAO-2 (e.g. Code and Meade, 1979, Ap. J. Suppl., 39, 195), Copernicus (e.g. Snow and Jenkins, 1977, *Ap. J. Suppl.*, 33, 269), TD-1 (e.g. Jamar et. al. 1976, *Ultraviolet Bright-Star Spectrophotometric Catalogue*, ESA 5R-27 or Thompson et. al., 1978, *Catalogue of Stellar Ultraviolet Fluxes*, Science Research Council) and ANS satellites.

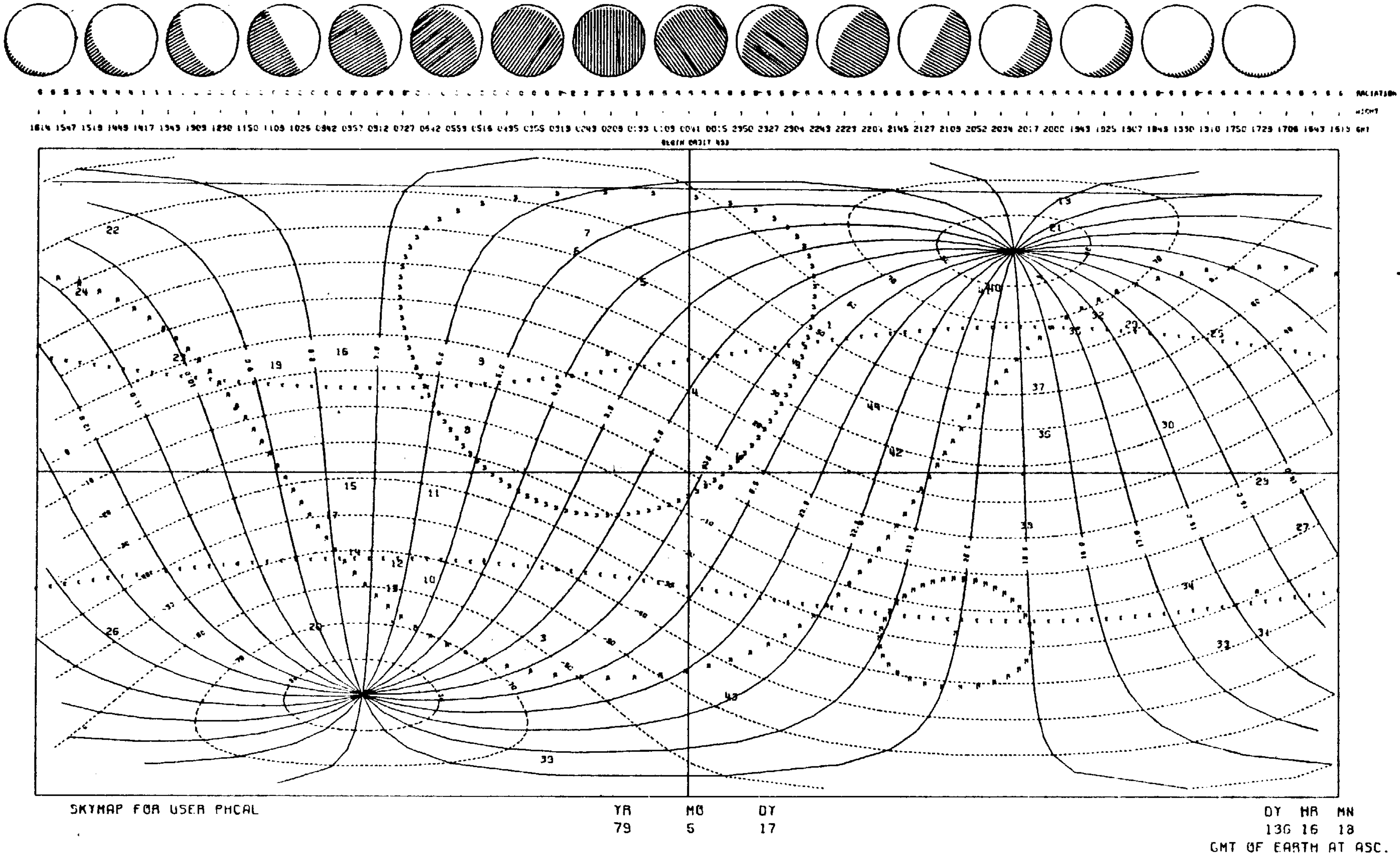

Figure 1. Sample Sky Map

Clever estimates may also be based on physical principles. The values of E_λ given above are based on the stellar flux calibration used by OAO-2 and Copernicus. TH1 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

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. Be sure to use the interstellar extinction curve (Bless and Savage, 1972, <u>Ap. J.</u>, 171, 293) when estimating fluxes for reddened stars from those for unreddened stars. Prior to their scheduled observations, Guest Observers will receive a computer listing of their targets with estimated exposure times for the specified observing modes. These exposures should be accurate to better than 30%. Guest Observers may get a better feeling for the exposure time by looking through the Observatory Log and talking to the Resident Astronomers after arriving at the Observatory.

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.

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

OBSERVER A. Holm & C. Wu

PROGRAM ID RCBAH

OBJECT R CrB

YEAR 1979

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 described in IUE NewsLetter # 3 by Don West.

CAMERA Long [✓ Short]

PREP [✓ Standard] Overexposed Fast None

Dispersion Mode High [✓ Low]

Large Aperture Close [✓ Open]

Object Aperture Small [✓ Large]

EXP Time 240 min ___ sec

PROCESSING SPECIFICATIONS

*** NO DEFAULTS ***

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

EXP Gain [✓ Max] Med Min

READ Gain [✓ Low] High NO READ

Remarks: PREP other than "STANDARD" and "OVEREXPOSED RECOVERY", EXP Gain other than "MAX", and READ Gain 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
Can be used to derive a visual magnitude.

Tracking Gyro FES Fast Slow

Focus Radiation Beta Roll

camera temperature

EXP Start GMT Day ___ Hr ___ Min ___ THDA IN EXP = ______

READ Start GMT Day ___ Hr ___ Min ___

Archive Tape ______ Image Sequence # ______

EMISSION LINE = ______ DN, or ______ X OVER.

CONTINUUM = ______ DN, or ______ X OVER. NOISE:

BACKGROUND = ______ DN, or ______ X OVER.

The number assigned here will be used to identify all output products related to this spectrum.

Comments

Figure 2a. A Typical Observing Script for a Low dispersion spectrum covering the 1150 Å To 2000 Å Region.

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

OBSERVER Schiffer

PROGRAM ID PHCAL

OBJECT η UMa

YEAR 1979

RA (1950) $13^{hr}\ 45^{m}\ 34.^{s}3$

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 for sensitivity monitoring. Overexposed prep is used to remove residual image remaining after previous saturated spectrum.

RA/TO Schiffer / Ehlers

Observatory Record Number 5564

FES Counts Out 5008 In 2019 Overlap [✓ Underlap]

FES [✓ Fast] Slow

Tracking [✓ Gyro]

Focus −2.4

Radiation 0.8

Beta 56°48′18.″1

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 58:20

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 3230Å region.

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.

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^o to 6^o 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 anti-sun it may be necessary to slew 360^o even though the shortest distance between them is less than a degree.

Maneuvers normally require 5 to 10 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	
(DN/hour)	%saturation/hour	1979	1978
≤ 20	≤ 8 %	20 %	7 %
20-40	8-16	34	11
40-100	16-40	26	23
100-300	40-120	10	27
≥ 300	≥ 120	10	33

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

(c) 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 pedistal 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.

(d) Efficiency. As the above sections indicate there is considerable overhead time involved in obtaining any IUE spectra. The TOs try to minimize the overhead by PREPing cameras while maneuvering and by reading one camera while the other is being exposed. 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 ~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. Trailed Spectrum - The signal to noise ratio can be greatly increased by obtaining widened spectrum. The star is trailed along the long axis of the large aperture by slewing the spacecraft at a controlled rate. For the same exposure level, a trailed spectrum requires three to four times the exposure time of an untrailed spectrum. Slew rates depend on the exposure time, and one or more passes can be made through the large aperture.

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 1979 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 should 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 ± 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 P.M. for lunch. To help cover those intervals when the cafeteria is closed, the Observatory has a refrigerator and a micro wave 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 (Nature, Vol. 275, pp. 372-415, 1978). Pasachoff et al. (Sky and Telescope, Vol. 57, pp. 438-443, 1979) describe a typical observing run with only a few inaccuracies.

For further information IUE Resident Astronomers (Al Holm, Skip Schiffer, and Charlie Wu for operations and Barry Turnrose and Kit Harvel for image processing) 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.

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