IMPROVEMENTS TO THE ACCURACY OF THE IUE WAVELENGTH SCALES IN HIGH DISPERSION*

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ABSTRACT

The data base of Pt-Ne emission lines used to calibrate the IUE high dispersion wavelength scales has been scrutinized to improve the internal consistency of the adopted laboratory wavelength values and provide a homogeneous, documented line list, which IUE Guest Observers may use to evaluate quantitatively those Pt-Ne spectra taken to calibrate their data. After deletion of incorrect or inappropriate data in the old data base (lines with incorrect wavelength assignments; lines which are too faint, too bright, or blended; lines which fall near reseau marks, etc.) and the addition of several new entries, a total of 172 Pt-Ne lines for the SWP camera and 164 Pt-Ne lines for the LWR camera are now used for routine wavelength calibration in the high dispersion mode. The internal one sigma scatter of the assigned wavelengths corresponds to 0.32 pixels along the dispersion direction for SWP (2.5 km s^{-1} velocity uncertainty) and 0.26 pixels along the dispersion direction for LWR (1.9 km s^{-1} velocity uncertainty). Thermal effects, which can introduce large systematic image shifts, are excluded from these uncertainties but are independently correctable, in principle.

In addition, new software has been written to calculate the wavelength corrections needed to reduce the extracted IUE high dispersion wavelengths to a heliocentric coordinate system. Two subroutines separately calculate the instantaneous velocity components due to the satellite motion about the earth (accurate to $\pm$ 0.25 km s^{-1}) and the earth's orbital motion about the sun (accurate to $\pm$ 0.01 km s^{-1}). The velocity corrections in the line of sight to the target will become part of the standard data reduction procedures under the new software system to be implemented this year.

INTERNAL ACCURACY

IUE wavelength scales are determined by Pt-Ne spectra from onboard hollow cathode lamps. A data base (or line library) of Pt-Ne emission lines and laboratory wavelengths for each spectrograph and dispersion mode is used in conjunction with measurements of the positions of the emission lines in the calibration images to define polynomial fits (ref. 1), which functionally relate pixel location to wavelength and

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order number. These dispersion relations are subsequently used in the spectral extraction process to assign wavelengths, and so the accuracy of the line libraries is crucial to the accuracy of the IUE wavelength scales. Thermal effects, which can introduce large systematic image shifts, are another factor in the accuracy of the IUE wavelength scales. Such effects are in principle independently correctable and are discussed elsewhere in this volume (ref. 2).

Although the IUE wavelength scales in high dispersion suffer no known serious deficiencies, an analysis of the high dispersion line libraries for the LWR and SWP cameras was undertaken for several reasons. First, it was observed that many lines were chronically rejected from the solutions for the dispersion formulae; this was suggestive of erroneous or inappropriate data in the line libraries. Second, spot checks showed the data in the libraries to be inhomogeneous and largely undocumented. This, too, suggested that inappropriate data might be included in the line libraries. The removal of inappropriate data is important because of the danger that noise in the images could otherwise occasionally be erroneously identified as a non-existent line. Third, it was felt that the organization of the line libraries into a homogeneous, consistent, and documented line list would be of value to IUE users by allowing them quantitatively to evaluate those Pt-Ne spectra taken to evaluate the wavelength accuracy of their data. The details of the line library analysis to be discussed here have been presented in the NASA IUE Newsletter (ref. 3). In the remainder of this section, we briefly summarize the steps and the conclusions of the analysis.

All entries in the original high dispersion line libraries (219 lines in LWR, 243 lines in SWP) were checked against available published references to verify the laboratory wavelength assignments and document the ionic origin. Where necessary, library entries were modified to agree with the published references according to a hierarchical ordering of preferred references. Lines for which no published reference could be found were deleted from the libraries.

All of the "chronically rejected" lines (i.e., lines rejected more than 50% of the time in a sample of more than 20 separate solutions in each of the SWP and LWR cameras) were examined on photowrite prints including some early annotated large scale prints prepared by T. R. Gull of GSFC and on plots of spectra extracted from the calibration images. There were 65 such lines in SWP, and 57 such lines in LWR. Most could be understood as being inappropriate because they were too bright, too faint, blended, near reseau marks, off of the tube face, or having apparently incorrect wavelengths in the published references. In all such cases, the lines were deleted from the libraries. Only a small number of the frequently rejected lines (4 lines in SWP, 7 lines in LWR) could not be reasonably explained and were left in the libraries.

The current analysis did not make a systematic attempt to add new lines to the edited libraries. In several instances, however, new entries were made and their accuracy verified by testing on several different Pt-Ne images. In all, 5 new lines were added to the library for each camera.

Table I summarizes the evolution of the SWP and LWR high dispersion line libraries. In the row marked "No. of Chronically Rejected Lines," the numbers in parentheses indicate the number of lines always rejected. Further details on the lines deleted from the original libraries, as well as a complete and documented listing of the new libraries, may be found in ref. 3. The new line libraries defined in accordance with the changes summarized in Table I have been in use since 18 April 1980. Prior to implementation in production processing, they were tested to insure their validity and to determine whether any improvement in the overall scale or internal accuracy of high dispersion wavelength calibrations results from their use. No change in the scale or zero points of the dispersion relations obtained with the new libraries was observed to an accuracy of one tenth of a pixel. This is not a surprising result since the majority of the lines deleted in arriving at the new libraries were generally rejected from the solutions using the old libraries.

The new libraries do, however, yield solutions with somewhat higher internal accuracy as judged by the standard deviations of the emission line positions calculated from the fitted dispersion formulae, compared to the exact emission line positions found by a two dimensional cross-correlation search technique. These standard deviations are measured separately in the line direction, σ (L), and the sample direction, σ (S). Table II summarizes the behavior of wavelength solutions obtained using the old and new libraries for several different Pt-Ne images in each camera. Note that the dispersion relations using the new libraries consistently employ a large fraction of the total number of available lines in the final solutions. This implies that the major sources of systematic error in the library entries have probably been eliminated, lending further credence to the consistency of the final libraries. The typical one sigma scatter in a given direction of 0.32 pixels for SWP and 0.26 pixels for LWR corresponds to a one sigma velocity uncertainty of 2.5 km s^{-1} in SWP and 1.9 km s^{-1} in LWR. These values are largely due to the inherent inaccuracies in the IUE geometric correction and line-finding algorithms and should be close to the errors expected in an arbitrary spectrum of an astronomical source obtained in the small aperture. Any additional errors should be caused only by thermal shifts in the cameras and spectrographs, which are being analyzed for a future discussion in the NASA IUE Newsletter.

CORRECTION TO HELIOCENTRIC WAVELENGTHS

The resolving power (R = λ/FWHM) of the IUE spectrographs varies from 1.0 X 10^4 to 1.5 X 10^4 over the entire wavelength range covered (ref. 1). Therefore the IUE velocity resolution varies from 20 km s^{-1} to 30 km s^{-1}. If it is assumed that the centroid of a line can be determined to approximately 10% of its FWHM, then a measured radial velocity should be accurate to about 2 km s^{-1} (best case). The orbital velocity of the Earth about the Sun (~30 km s^{-1}) and the velocity of the spacecraft about the Earth (~4 km s^{-1} at perigee) are both larger than the best possible velocity determinations and their effect should be removed from the data.

Two subprograms have been written for IUESIPS, the International Ultraviolet Explorer Spectral Image Processing System, to calculate orbital velocities. One of these determines the velocity vector of the Earth at a given time using the orbital elements of the Earth and the time derivatives of these elements as given in ref. 4. The other program determines the velocity vector of the spacecraft about the Earth at a given time using all the orbital elements of the spacecraft for Nov. 22, 1979 except for the period, which is set to exactly one sidereal day. Since the orbit of the spacecraft is periodically adjusted to maintain a sidereal period and, moreover, an approximately fixed ground path, it is not necessary to update the orbital elements used by the program. This program is accurate to ± 0.25 km s^{-1} over the entire life of the spacecraft (launch to present). Both of these subprograms will be added to IUESIPS in the near future and a detailed description of them, including a FORTRAN listing, will be published in the NASA <u>IUE Newsletter</u>.

REFERENCES

1. Boggess, A., et al.: In-Flight Performance of the IUE. Nature, vol. 275, Oct. 1978, p. 377.

2. Thompson, R. W., Turnrose, B. E., and Bohlin, R. C.: Effects of Temperature Fluctuations on IUE Data Quality. The Universe in Ultraviolet Wavelengths: The First Two Years of IUE. NASA CP-2171, 1980: this compilation.

3. Turnrose, B. E., and Bohlin, R. C.: IUE Data Reduction XVI. High Dispersion Line Libraries. NASA IUE Newsletter, 1980.

4. American Ephemeris and Nautical Almanac.

TABLE I. - CHARACTERISTICS OF NEW AND OLD LINE LIBRARIES

	SWP	LWR
No. Lines in Old Library	243	219
No. Chronically Rejected Lines	65 (29)	57 (15)
No. Lines Deleted	76	60
No. Lines Added	5	5
No. Lines in New Library	172	164

TABLE II. - CHARACTERISTICS OF SOLUTIONS USING NEW AND OLD LINE LIBRARIES

	New Line Library			Old Line Library		
Image No.	σ (L) px.	σ (S) px.	Fraction of lines used	σ (L) px.	σ (S) px.	Fraction of lines used
SWP5419	.35	.31	.93	.40	.36	.72
SWP6349	.34	.29	.93	.38	.37	.74
SWP6699	.34	.30	.90	.40	.36	.74
SWP8266	.36	.29	.91	---	---	---
MEAN	.35	.30		.39	.36	
LWR4656	.26	.28	.95	.26	.28	.76
LWR5483	.27	.30	.93	.27	.34	.75
LWR5725	.26	.27	.93	.26	.30	.73
LWR7205	.26	.24	.93	---	---	---
MEAN	.26	.27		.26	.31	