EFFECTS OF TEMPERATURE FLUCTUATIONS ON IUE DATA QUALITY*

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ABSTRACT

Analysis of IUE calibration lamp images has shown that variation in the temperature of the scientific instrument causes shifts in the location of the spectral format with respect to the reseau grid on the detector and in the location of the reseaux themselves. In high dispersion, a camera head amplifier temperature difference of 6C corresponds to a shift of 4 pixels in the spectral format for LWR and 2 pixels for SWP along the dispersion direction. Shifts perpendicular to the dispersion (for the same temperature difference) are less than one pixel for both cameras. In low dispersion spectra, the shifts are similar but orthogonal to those described above with the larger motion lying in the direction perpendicular to the dispersion. In both dispersion modes, the observed shifts are apparently independent of wavelength. In high dispersion, the constant pixel shift mimics a constant velocity error.

Studies of reseau motion support earlier findings that decreases in temperature lead to an overall expansion of the grid of reseaux. For example in SWP, reseaux near the edge of the tube were found to move ~1.5 pixels with a temperature variation of 9 C.

Procedures are under development for utilizing these temperature correlations to correct the dispersion-relation and reseau-position files to the temperature of each target image and thereby achieve improved wavelength and photometric accuracy in reduced IUE spectra.

INTRODUCTION

Dispersion relations and reseau positions for IUE images have historically been determined and updated at approximately biweekly intervals from sets of standard calibration images consisting of Pt-Ne exposures superposed on tungsten-flood (TFLOOD) backgrounds. Since July 1978 reseau positions have been measured exclusively on the low dispersion Pt-Ne-plus-TFLOOD images to avoid the occasional contamination of reseaux caused by the presence of a high dispersion Pt-Ne spectrum. Approximately forty sets of reseau positions and dispersion constants have so far been accumulated in this manner for each camera and dispersion mode.

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Although it has been known that the dispersion relations and reseau positions determined from the biweekly calibrations exhibit significant variation, and that this variation was suspected to be a direct consequence of thermal influences, there has heretofore been no detailed study quantitatively relating the observed variations in spectral position to measurable temperatures. The current work presents the first results of such an analysis: remarkable correlations of spectral position with camera head amplifier temperatures (THDA). It also presents results which confirm earlier studies suggesting that temperature changes induce a measurable expansion/contraction of the grid of reseau positions. In the sections to follow we discuss separately our studies of spectral format and reseau motion.

SPECTRAL FORMAT

The motion of IUE spectra with respect to the camera tube face has long been observed (ref. 1), and the standard IUESIPS (IUE Spectral Image Processing System) reduction procedures routinely incorporate a spectral registration step for each image which compensates for the component of spectral motion perpendicular to the dispersion direction. Because the component of spectral motion parallel to the dispersion direction cannot presently be removed without recourse to accurate spectral feature identification, there is no practicable means of correcting for this motion in a routine way on all spectra at the time of processing. In an attempt to better understand the nature of the spectral shifts in IUE images, and with the hope that such an understanding would lead to the means of correcting for the shifts, a study of the available calibration images acquired during the first two years of operation of IUE was undertaken. In this study, the fitted dispersion relations functionally relating pixel location to wavelength and order number (ref. 1) for the low and high dispersion modes in both the SWP and LWR cameras were used to trace the movement of particular wavelengths within the image line and sample grid from one calibration to the next. Initially displayed as line and sample coordinates vs time, these data illustrated that, for a given camera, changes in spectral location were the same in either dispersion mode. Further investigation showed that the spectral shifts appeared to correlate with several of the available temperatures monitored in the scientific instrument. In particular, the camera head amplifier temperature, THDA, was chosen as a convenient thermal parameter because its value at the time of image exposure and/or read is available directly from the Observatory Record sheets for many images, from printed listings of hourly camera snapshots (maintained by the IUE OCC) for many other images, and also from the science header on Guest Observer tapes for images acquired since 14 March 1979. Linear least squares regression analysis revealed remarkable correlations of the observed spectral motions with THDA. These correlations were remarkable not only because they revealed quantitative evidence for the thermal nature of the observed shifts, but also because THDA is a direct measurement of a camera temperature, and as such, is only an indirect measure of thermal conditions within the spectrographs themselves. The significant correlation of spectral motion with THDA indicates that THDA is in most instances a good measure of the thermal conditions giving rise to the spectral shifts, which presumably originate within the spectrograph portion of the scientific instrument. (A notable exception to the correlation is discussed below). Since the reseau positions used to geometrically correct the Pt-Ne images in this analysis were measured directly on the low dispersion Pt-Ne-plus-TFLOOD images, and since no high dispersion Pt-Ne images were considered if they were obtained more than 3 hours earlier or later than the accompanying low dispersion image, none of the spectral shifts discussed here should be attributable to reseau motion.

The observed spectral shifts were transformed for each camera and dispersion mode into orthogonal components parallel and perpendicular to the dispersion direction. Such a coordinate system is convenient in particular because it reveals the magnitudes of the observed shifts along the direction for which compensation is currently not made. Figures 1-4 display the relative shifts parallel to the dispersion, plotted against THDA, for the four possible camera/dispersion mode combinations. A positive shift is a shift in the direction of increasing wavelength, and all shifts are shown relative to the mean of the displayed points. The straight lines in Figures 1-4 are the linear correlations of the shift and temperature calculated by least squares regression.

In Figures 1 and 2, the relative shifts and fitted straight lines for three distinct wavelengths are shown. Although there is a perceptible difference in the slope of the three fitted relations in each of these figures, it appears that the differences can be explained by the scatter of the data. We conclude that the thermal spectral shifts are constant pixel shifts within the accuracy of measurement $\sim\pm 0.3$px. Such a situation mimics a constant velocity shift in the extracted spectra of high dispersion images and is the likely cause of the velocity-like wavelength errors recently reported by Leckrone (ref. 2). In Figures 1 and 2 the fitted linear relation to the plotted data for the first wavelength listed is given in equation form at the lower right; in Figures 3 and 4 the equation pertains to the data plotted. In all four figures the error bars shown correspond to the least square fitting errors in pixels and to the quantization of the recorded temperature values.

Not shown here are the correlations of shifts perpendicular to the dispersion with THDA. As a point of interest, whereas the shifts parallel to the dispersion are greater than those perpendicular to the dispersion in high dispersion, the reverse is true in low dispersion because of the orthogonality of the low and high dispersion orders. Data on these shifts will be included in the complete documentation of this work being prepared for distribution in the NASA IUE NEWSLETTER.

It should be noted that the point in Figure 2 marked by an "X" was not included in the correlation computation. This datum was obtained with the spacecraft pointed close to the anti-sun direction, and in a configuration in which the spectrographs became hotter than the cameras. Such a condition apparently represents a limitation to the degree to which THDA can be used to predict spectral shifts. Although correlations with other available temperatures are being investigated, it is likely that extreme thermal configurations will always be difficult to model.

RESEAU MOTION

Independent of the motion of the spectral format on IUE images, the measured positions of reseau marks are known to change from one calibration image to the next due to a slight thermal sensitivity of the camera readout electronics. A separate study of the behavior of reseau positions as a function of temperature has been initiated in light of the successful correlation of spectral shifts with temperature described in the previous section. As with spectral shifts, a better understanding of the nature of the observed behavior might allow for corrections that could improve the quality of the reduced IUE data. In the case of reseaux, an improved geometric correction resulting from improved reseau positions would yield an improved photometric correction as well as improved spectral placement.

In analyzing the available body of data on reseau positions, it was deemed advantageous to utilize the available archives of UVFLOOD flat-field exposures rather than the standard set of low dispersion Pt-Ne-plus-TFLOOD exposures. This is because subtle complications in determining reseau positions can arise from the presence of the low dispersion Pt-Ne spectra on the TFLOOD flat fields, and such complications could mask the relatively subtle thermal effects under study. As a result, for the present study new measurements of reseaux on some 16 LWR and 20 SWP 60% UVFLOOD images acquired over the first two years of IUE operation were analyzed. The new measurements employed a cross-correlation template better matched to the large fiducial reseau, the addition of three more reseau positions in each camera near the tube edges, and the suppression of the standard smoothing of found reseau positions, which uses a polynomial curve fitting technique. Further details of all the above considerations are being prepared for the NASA IUE NEWSLETTER.

Figures 5 and 6 summarize the results of the temperature-dependence studies of reseaux so far conducted on in-flight images. These figures represent three separate sets of reseau measurements, each corresponding to a different THDA value. The diamond symbols indicate the positions of a low-temperature reseau set. From these positions, the displacements (magnified according to the scale indicated on the figures) are drawn to the location of all corresponding reseaux from two higher-temperature images. The actual THDA values are given in the figure captions.

Notice that reseau positions near the tube edge for SWP shift as much as ~ 1.5 pixels with a change in head amplifier temperature of 9 C. Both LWR and SWP exhibit a general eccentric contraction of the overall reseau grid with increasing temperature, in agreement with previous studies (ref. 3). Reseau studies are continuing in order to refine the initial results presented here.

DISCUSSION

Motivating both the spectral format and reseau motion studies is the desire to improve the quality of reduced IUE spectra. It is our intent to further codify the temperature dependence of reseau behavior and then ultimately develop in IUESIPS the capability of utilizing mean dispersion constants and reseau positions which can be temperature-corrected on the basis of THDA values or read directly and decoded from the spacecraft snapshots of the image science headers. It is anticipated that significant improvements in photometric and wavelength accuracy over that currently achievable with biweekly calibrations and mean low resolution dispersion constants (ref. 4) could be realized with temperature-corrected calibrations. It should be noted in this regard, however, that ref. 3 states that the ultimate effectiveness of temperature-correction schemes for reseau positions depends on the magnitude of beam-pulling effects within the cameras (i.e., the influence of the distribution of illumination within the image on the placement of the camera read beam).

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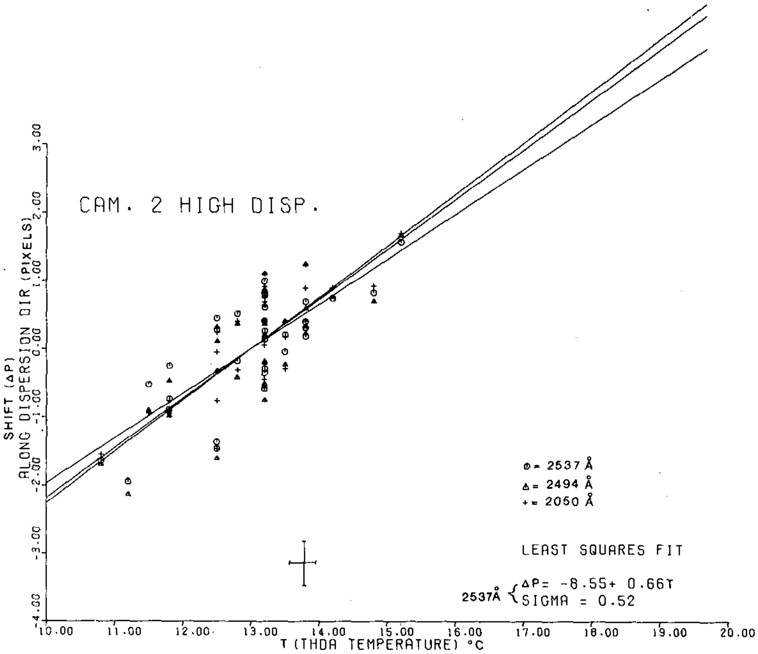

Figure 1 Camera 2 (LWR) high dispersion spectral format shifts along the dispersion relative to the mean as a function of camera head amplifier temperature. Data for 3 different wavelengths are plotted.

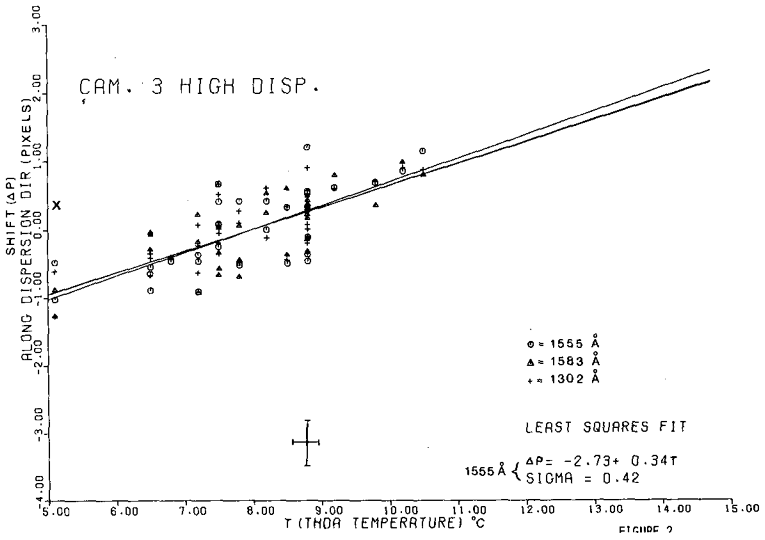

Figure 2 Camera 3 (SWP) high dispersion spectral format shifts along the dispersion relative to the mean as a function of head amplifier temperature. Data for 3 different wavelengths are plotted.

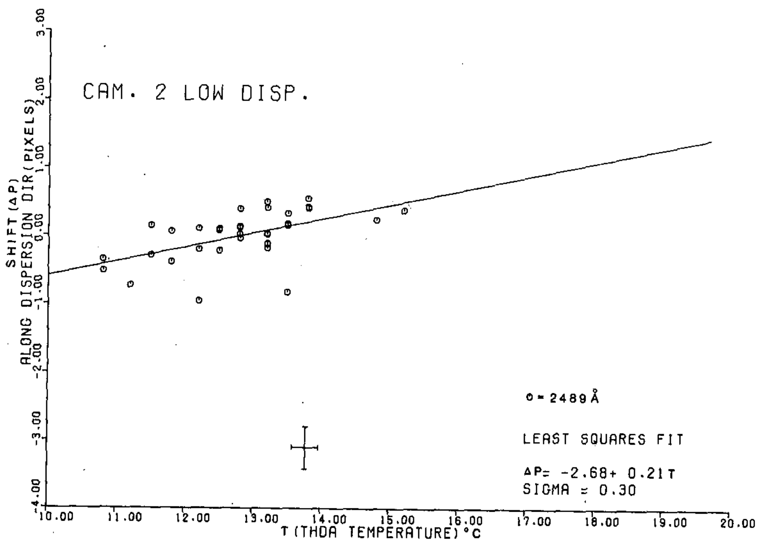

Figure 3 Camera 2 (LWR) low dispersion spectral format shifts along the dispersion relative to the mean as a function of head amplifier temperature.

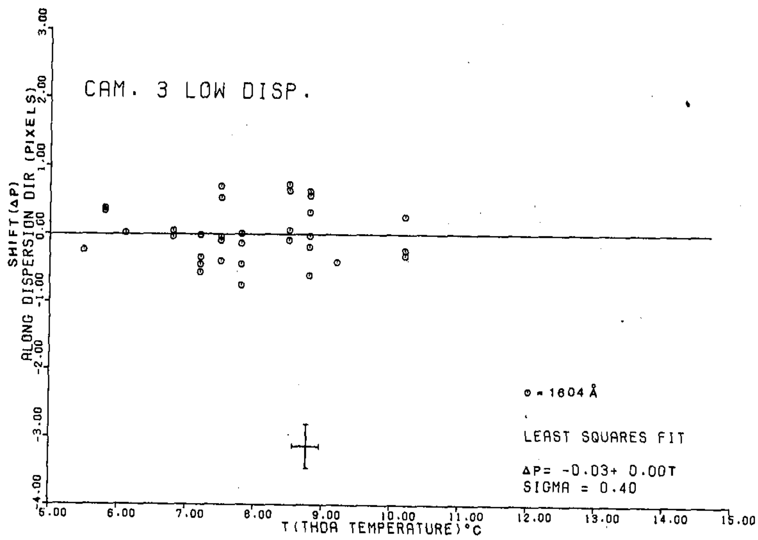

Figure 4 Camera 3 (SWP) low dispersion spectral format shifts along the dispersion relative to the mean as a function of head amplifier temperature.

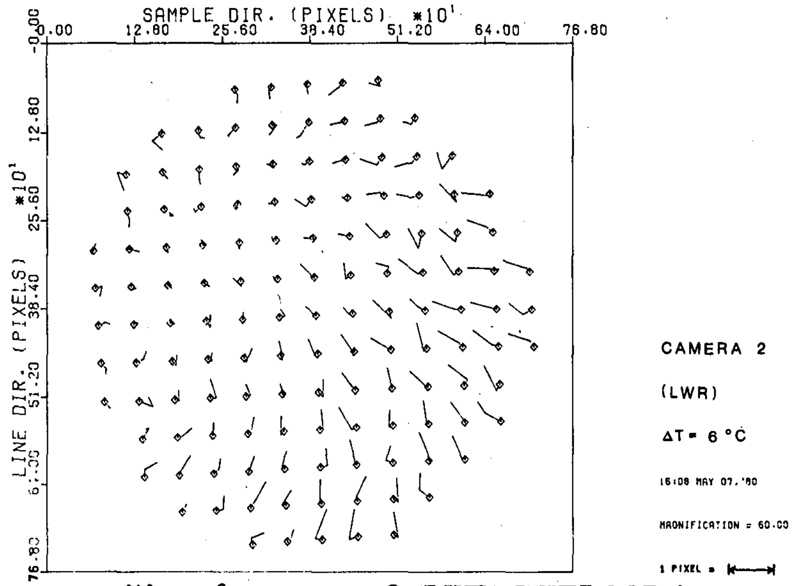

Figure 5 Reseau positions for camera 2 (LWR) UVFLOOD images at 3 different head amplifier temperatures. Diamond symbols are plotted at positions of reseaux for the lowest temperature (10.8 C). The lines are vectors representing the displacement of reseaux for the second and third temperatures (12.8 C and 16.9 C), relative to the first temperature and magnified by a factor of 60. The magnified displacement scale is shown graphically at the lower right.

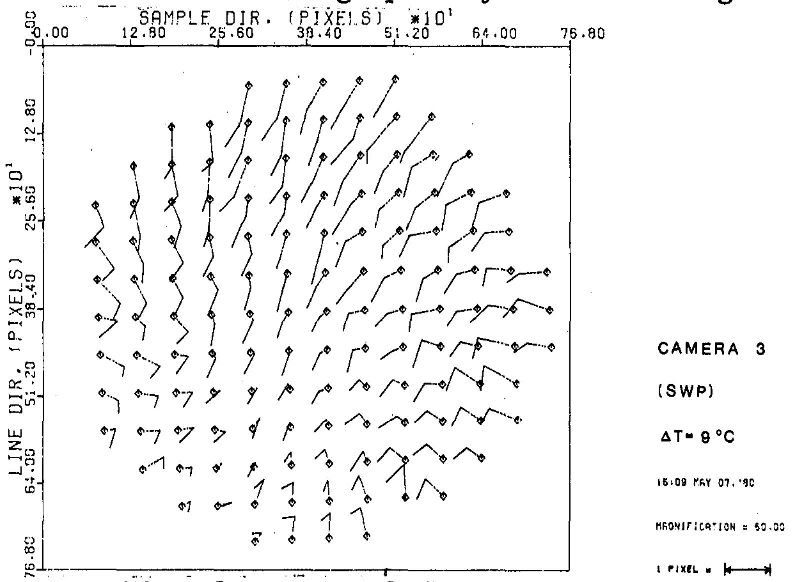

Figure 6 Reseau positions for camera 3 (SWP) UVFLOOD images at 3 different head amplifier temperatures. Diamond symbols are plotted at positions of reseaux for the lowest temperature (5.5 C). The lines are vectors representing the displacement of reseaux for the second and third temperatures (9.2 C and 14.2 C), relative to the first temperature and magnified by a factor of 60. The magnified displacement scale is shown graphically at the lower right.