Investigating the IUE ITF as a Model for the Camera "Fixed Pattern"

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Abstract

A study of the IUE cameras using the ITFs as a model shows the "Fixed Pattern" (FP) in the IUE cameras is most evident in the right side of each of the cameras, the SWP camera having fewer deviations compared to the LWP and the LWR cameras. Through modeling the random gaussian noise (photon noise) and comparing to an ITF template, the range of intensities is typically 50 DN. Using the FP as a fiducial may not be possible for the LWP and SWP cameras due to the lack of FP deviations in large areas where a significant fraction of the spectra lies.

I INTRODUCTION

To evaluate the possibility of using the "Fixed Pattern" (FP) in the International Ultraviolet Explorer (*IUE*) image data to geometrically correct the images, we must first examine its characteristics. In this evaluation we must address several questions: how strong is the FP? where can it be found? and how does it change with intensity? We must address each of these questions before the "Fixed Pattern" technique can be useable for all *IUE* data from all three cameras (LWP, LWR, and SWP). To examine the first three questions I will use the Intensity Transfer Function (ITF) levels as templates for the FP because through the construction of the ITF, several images are summed, and hence, the signal is increased with respect to the noise. Typically four to ten flat field (UV flood) exposures have been averaged to form one ITF level.

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Table 1: *IUE* Camera Sensitivities

Camera	Sensitivity S DN/photoelectron	S^{-1} photoelectron/DN
LWP	0.25	4.00
LWR	0.35	2.86
SWP	0.35	2.86

II Strength and Location of the Fixed Pattern

We can view the strength of the FP by comparing the deviations in the FP to those due to random gaussian (photon) noise. Thus the first step is to quantify the deviations in the ITF levels due to the FP. Local deviations in the ITF are derived by smoothing a given level with a two-dimensional 33-point boxcar function, which retains the gross overall structure of the ITF level but smooths out all of the pixel-to-pixel variation. The difference between the DN (data number) level for a given pixel and its local average gives a measure of the deviations in the ITF level due to all noise sources (eg. FP and photon noise). Averaging several UV-Flood images for each ITF level increases the signal with respect to the noise, though the noise is still present.

reduces the random noise though does not remove it.

Even though the *IUE* cameras are not photon counting detectors we can use photon counting statistics as a model of the minimum we can expect for sources and characteristics of random noise. Photon noise is given by $\sigma = \sqrt{n}$ where n is the number of photons. For the detectors used onboard the *IUE* we have to include the camera sensitivities S given by Coleman *et al.* (1977). Table 1 (from Coleman *et al.* 1977) lists the camera sensitivities for the three operational *IUE* cameras in units of Data Number (DN) per photoelectron. The minimum photon noise in single *IUE* images is given by $\sigma = \sqrt{DN \times S^{-1}}$. Thus for $DN = 100$ the minimum noise σ for a single image is 5 for LWP and 6 for LWR and SWP. For the ITF levels the noise is typically a factor of three to four smaller.

Any real FP in the *IUE* cameras can only be detected if the deviations are larger than those expected from photon noise in the ITF. However for the FP to be useful as fiducials for the geometric correction the deviations must also be larger than the photon noise expected in a single image. Figures 1, 2, and 3 show, for each of the three *IUE* cameras, all of the pixels that have deviations larger than two times the expected photon noise for a single exposure for ITF level 2. The striped pattern results from unintentional smoothing in the geometric correction algorithm applied to each of the UV-Flood images which co-aligns

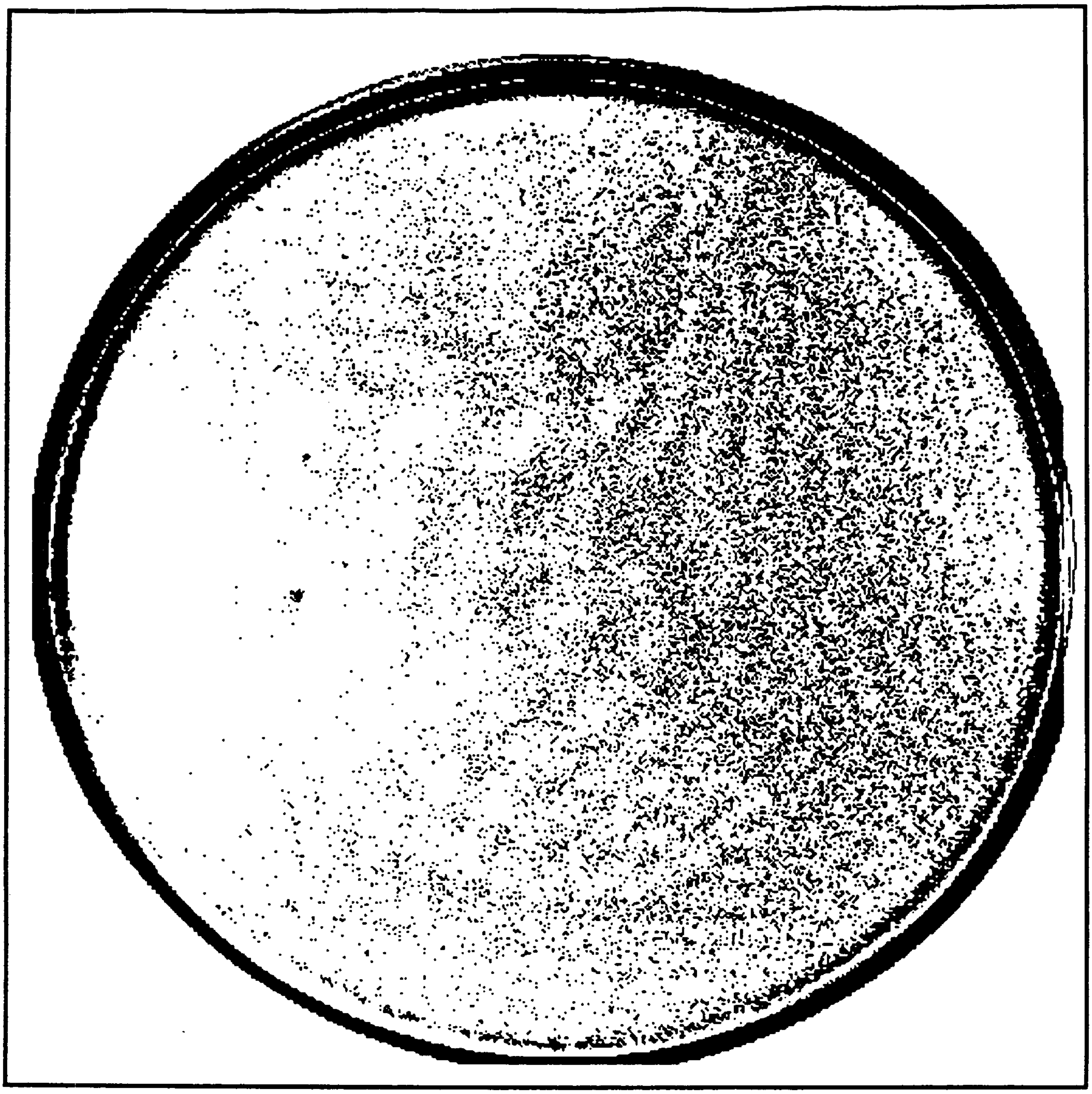

Figure 1: All pixels in the second LWP ITF level with deviations larger than two times that expected from photon noise for a single image are plotted. The striping is due to the smoothing introduced by the current geometric correction algorithm. Notice the left side has fewer pixels with deviations large enough to be plotted. Line and sample value (1,1) is in the upper left corner.

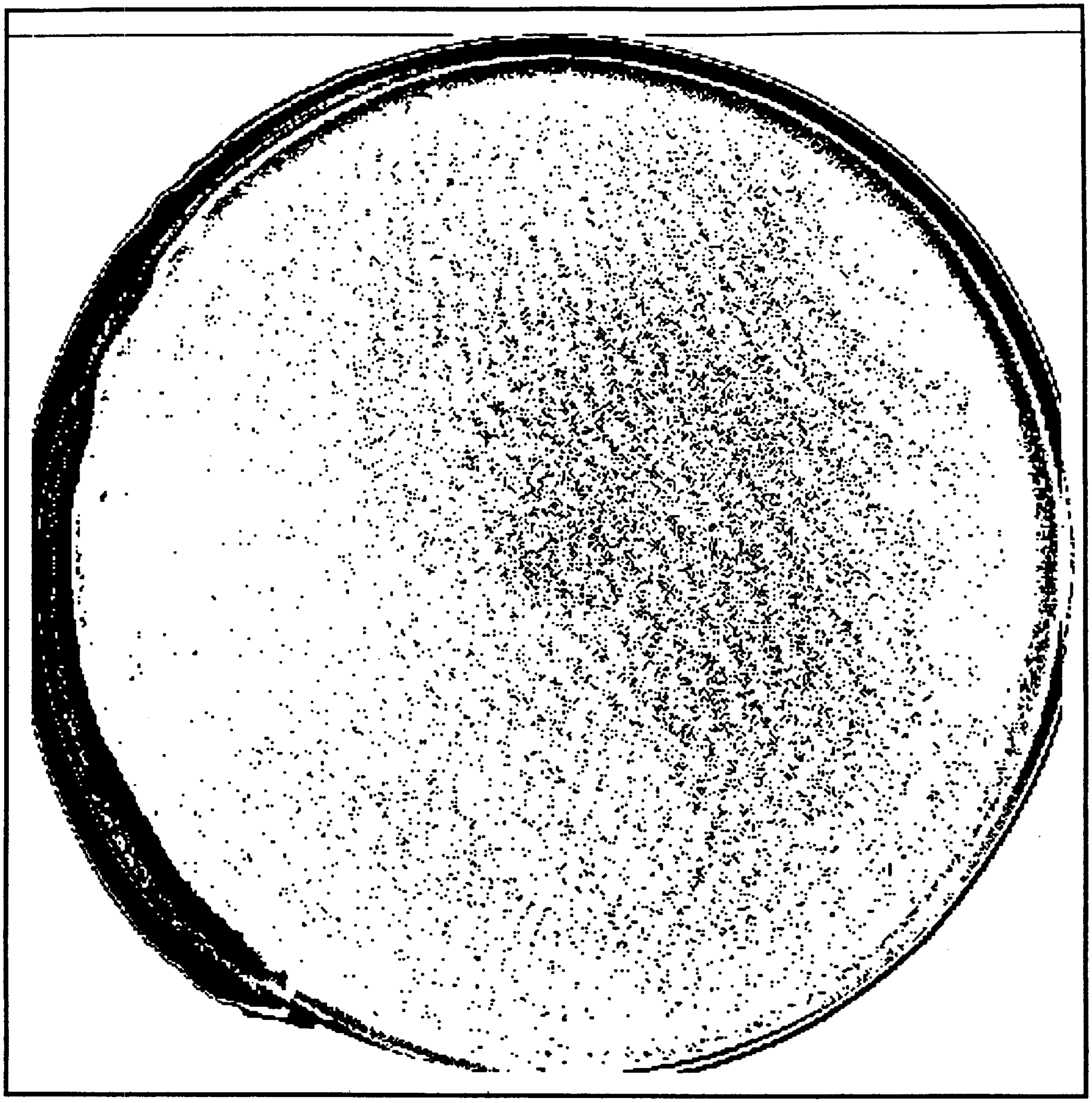

Figure 2: Same as Fig. 1 for the second LWR ITF level.

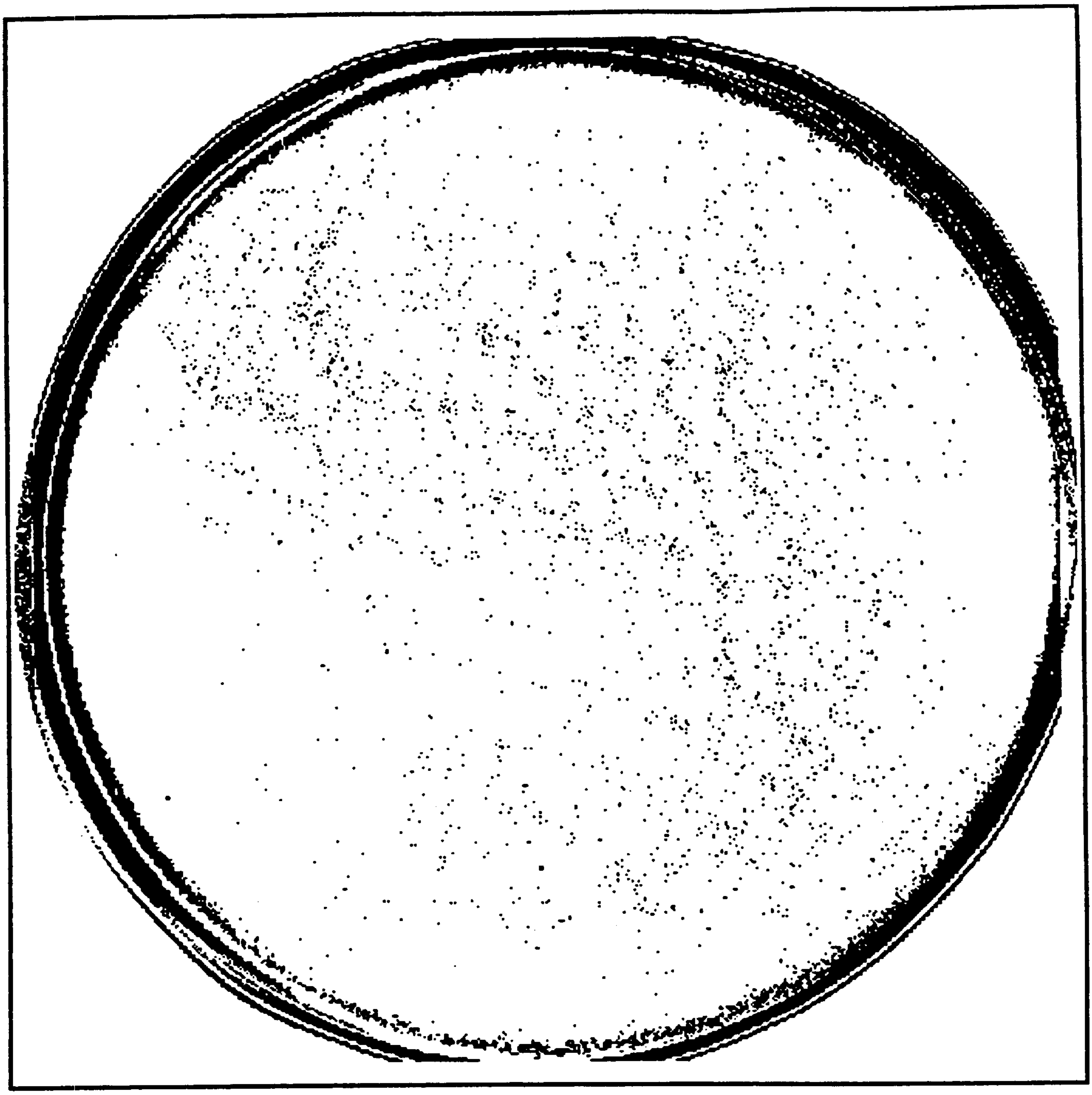

Figure 3: Same as Fig. 1 for the second SWP ITF level.

them for averaging. For each camera the left side has the smallest deviations; as a result it may not be possible to find the deviations reliably and use the FP as a fiducial. All levels of the ITFs behave in a similar fashion.

III Variation of the Fixed Pattern with Intensity

As discussed above the ITF should provide an example of what the FP should be, more independent of the photon noise than a single image. Using the ITF as an idealized model of how the cameras behave for each exposure, we may also construct a model of how the camera behaves for just photon noise on a single image. We create this photon-noise (PN) model image by adding normally distributed random numbers with the standard deviation of $\sigma = \sqrt{\langle DN \rangle \times S^{-1}}$ to an ITF level. We can study the effects of intensity on the FP by correlating small patches of a given ITF level with other levels and PN images. Comparing patches of a given ITF level to other levels evaluates the stability of the FP as a function of intensity. For example we can ask how rapidly does the FP change with DN level? Correlations of the ITF template patch to PN image patches allows us to examine the practical problem of using the ITF levels as templates of the FP to correlate with science images. Further, correlating PN images to other PN images evaluates the use of a single UV-Flood image as a FP template.

Figure 4 shows the confidence level for the correlations between the template patch of level 3 in the LWP ITF and all other levels of the LWP ITF. Notice for the ITF to ITF or ITF to PN image correlations the probability that the correlation results from random chance is less then 1% for ITF levels 2, 3, 4, and 5 representing an intensity range of $\approx$ 70 DN. While the PN image to PN image correlations result in the same probability only for ITF levels 3 and 4 or a range of $\approx$ 20 DN. High confidence values for correlations above ITF level 8 result from saturation of pixels in the those ITF levels and are not valid. All three cameras show similar results: a range of $\approx$ 70 DN for ITF to PN, and a smaller range ($\approx$ 20 DN) for PN to PN comparisons. As a result the ITF makes a better FP template than single UV-Flood images would.

IV Conclusions

A problem that must be addressed before the ITF levels can be used as FP templates is the smoothing caused by the geometric correction algorithm used in the construction of the ITF levels. This smoothing distorts the intrinsic FP as well as the science data during the photometric correction step in the *IUE* processing. This smoothing distorts the results of this study by locally reducing the number of pixels that deviate by more than two times the expected photon noise (see Figs. 1, 2, and 3).

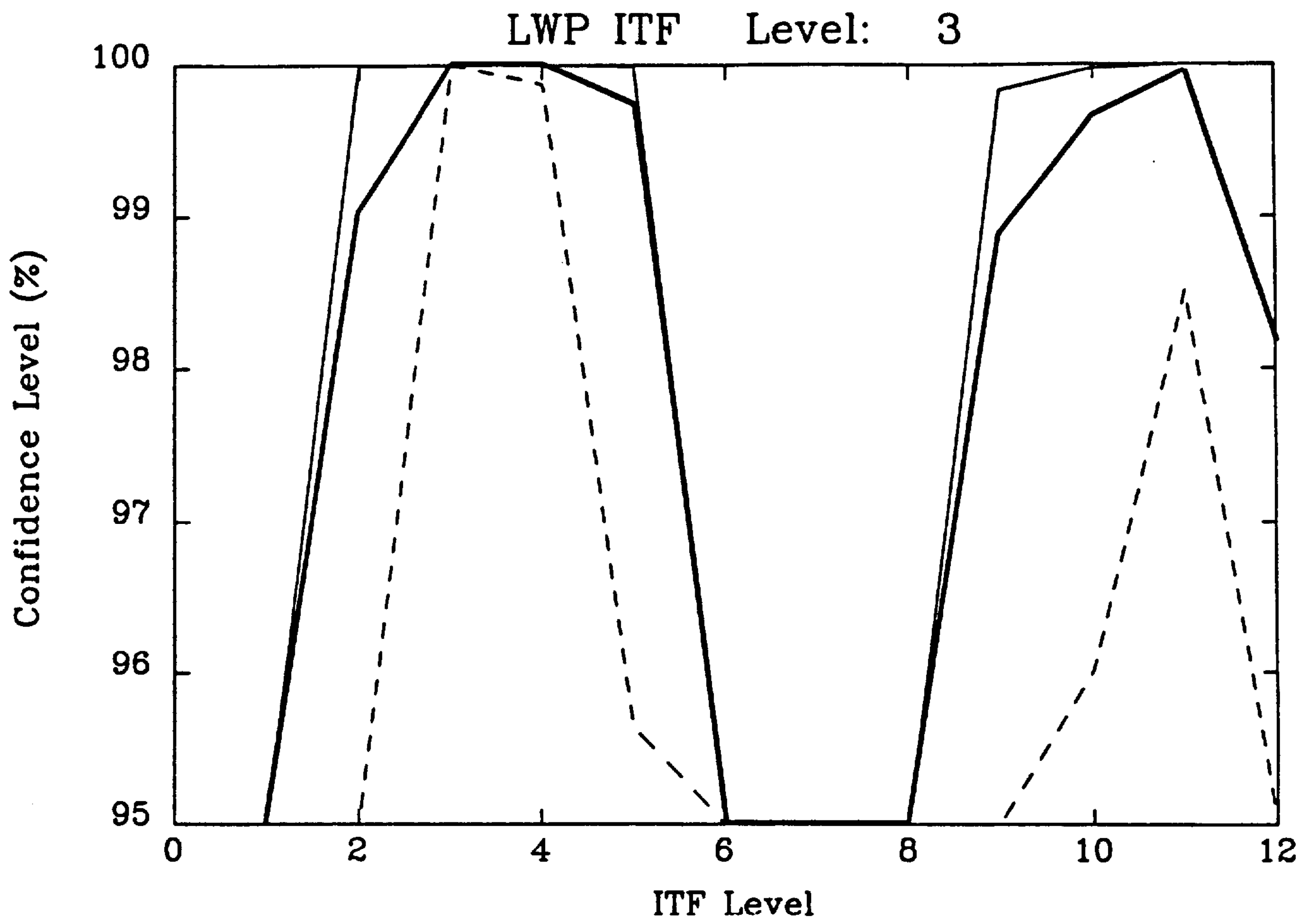

Figure 4: Comparison of correlations between level 3 of the LWP ITF with all other ITF levels. Pure FP to FP (ITF to ITF) is displayed as the thin solid line, FP to noise-image (PN) as the heavy solid line, and noise-image to noise-image (PN to PN) as the dashed line. This patch, a 7×9 pixel area near the center of an ITF level (centered at 303,304), is cross-correlated with the same location in all the rest of the ITF levels. NOTE: above ITF level 8 the central part of the camera is saturated, rendering these correlations suspect.

Briefly the major conclusions of this investigation are:

1. The "Fixed Pattern" is easily identifiable in each of the *IUE* ITFs.
2. The left side of each camera for all ITF levels has smaller FP deviations than the rest of the camera as compared to the expected photon noise for a single image.
3. The FP deviations for the LWR camera are more uniformly distributed than the deviations for either the LWP or SWP cameras.
4. The SWP camera has a much sparser distribution of FP deviations Than either LWP or LWR.
5. ITF levels have a larger useful range as FP templates than do the single UV flat field images resulting in higher probability of correlation for intensity levels near but not exactly the same as the single science image.
6. There is no need to interpolate between ITF levels to construct ITF templates.
7. The smoothing due to the geometric correction used in ITF construction will introduce distortions in the FP template as well as in the photometric correction of the science images.

Due to the "smooth" appearance of the left side of each camera using only the "Fixed Pattern" as a fiducial may not work for all science images. Other fiducial methods should be investigated along with the the FP. These results suggest that we must take great care in our understanding the applicability of the FP fiducial technique to all of the *IUE* archive. It may be possible to use the FP technique with some other indicator of the geometric distortion. In the regions where the FP has large deviations it should not be necessary to preform interpolations between ITF levels to create a suitable FP template. However the algorithm used to preform the geometric and un-geometric correction should be further investigated for methods to remove or reduce the smoothing. It should be noted that a significant portion of the spectra for both high and low dispersion are extracted from the small FP deviation (left side) part of the LWP and SWP cameras. As well as that most of the LWR spectra (both high and low dispersion) are in the larger FP deviation region of the camera.

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