Templates: A Brief Update

Daniel E. Welty
University of Chicago

At the first meeting of the Signal-to-Noise Improvement Group, we described a flat-fielding, or "template" technique for reducing the effects of the so-called fixed-pattern noise (FPN) present in IUE high-dispersion extracted spectra (Welty 1988a). Continued use of and experiments with this technique have provided some further information regarding the source and properties of the FPN.

As a part of an effort to produce the best possible interstellar absorption-line profiles from the high-dispersion IUE spectra of SN1987a (Welty, York, and Frisch 1988; see also Welty 1988b), we have constructed templates from archival spectra of η UMa for approximately 40 regions of the SWP camera and 20 regions of the LWP camera. We characterize the noise properties of the η UMa spectra by the rms fluctuations about unity after the spectra have been flattened and normalized by a high-order polynomial, and display the noise as a function of order number for both cameras in Figure 1. This figure shows (from bottom to top) the noise in a typical individual spectrum (ind), the noise in the sum of 15 spectra (sum), the noise in the template spectrum (presumably reflecting the FPN) constructed from those 15 spectra (tmp), the computed random noise present in a typical individual spectrum (rnd = sqrt(ind**2 - tmp**2)), and the mean net flux in a typical individual spectrum. If the FPN (as characterized by tmp) is produced by some multiplicative process, we would expect tmp to be roughly constant, independent of the mean net flux (assuming that the background is negligible). Conversely, if the FPN is additive, we would expect an inverse relationship between the two quantities. As both types of behavior seem to be present for different regions of the two cameras, the FPN is probably neither simply additive nor simply multiplicative.

We have compared templates constructed from the same spectra processed with both the old and the recently-constructed SWP intensity transfer functions (ITFs) in an attempt to address the question of whether the FPN could be due to noise in the ITFs. Table 1 presents the results of those comparisons for five representative regions of the SWP camera (several near the tube edges, several near the middle). In each case, the first and second lines give the noise characteristics (as described above) for the old and new ITFs, respectively. Apart from a possible slight (<

10%) decline in the noise in the templates, the noise characteristics are almost identical. The relative offsets among the spectra are essentially exactly the same for the two sets of spectra (apart from a slight change in the wavelength scale apparently due to a slightly different implementation of time and temperature corrections), and, as seen for example in Figure 2, the resulting templates are **very** similar. Cross-correlation of old and new templates yields a clear minimum (60 to 70% reduction) in the rms deviation between the two spectra. This excellent agreement between templates constructed from spectra processed with the old and new ITFs would seem to imply that noise in the ITFs is not a major source of the FPN.

Finally, we have attempted to automate the production and application of templates to a greater degree; we present some estimates for CPU and clock time (min:sec) for various steps involved in the processing. The programs run on a Sun 2 workstation; the figures given are for processing 15 spectra of 275 points each, using a 19th order Legendre polynomial to flatten and normalize the spectra. These are times for the current implementation; the various processes can almost certainly be further optimized and automated, though some interaction will still be necessary in determining how to flatten the spectra and, in some cases, in determining the correct relative offsets among spectra.

	CPU	clock
1) extract net spectra from MEHI files	0:22	1:25
2) read & sum extracted spectra to examine and determine necessary flattening	0:25	1:15
3) read & flatten spectra, determine offsets, and construct template or read & flatten spectra, determine offsets with respect to template	~1:00	~20:00
4) read extracted spectra, divide by shifted template, sum divided spectra	0:32	2:20

References

Welty, D.E. 1988a, NASA IUE Newsletter No. 34.

Welty, D.E. 1988b, IUE Tenth Anniversary Symposium, panel discussion.

Welty, D.E., York, D.G., and Frisch, P.C. 1988, IUE Tenth Anniversary Symposium, poster paper.

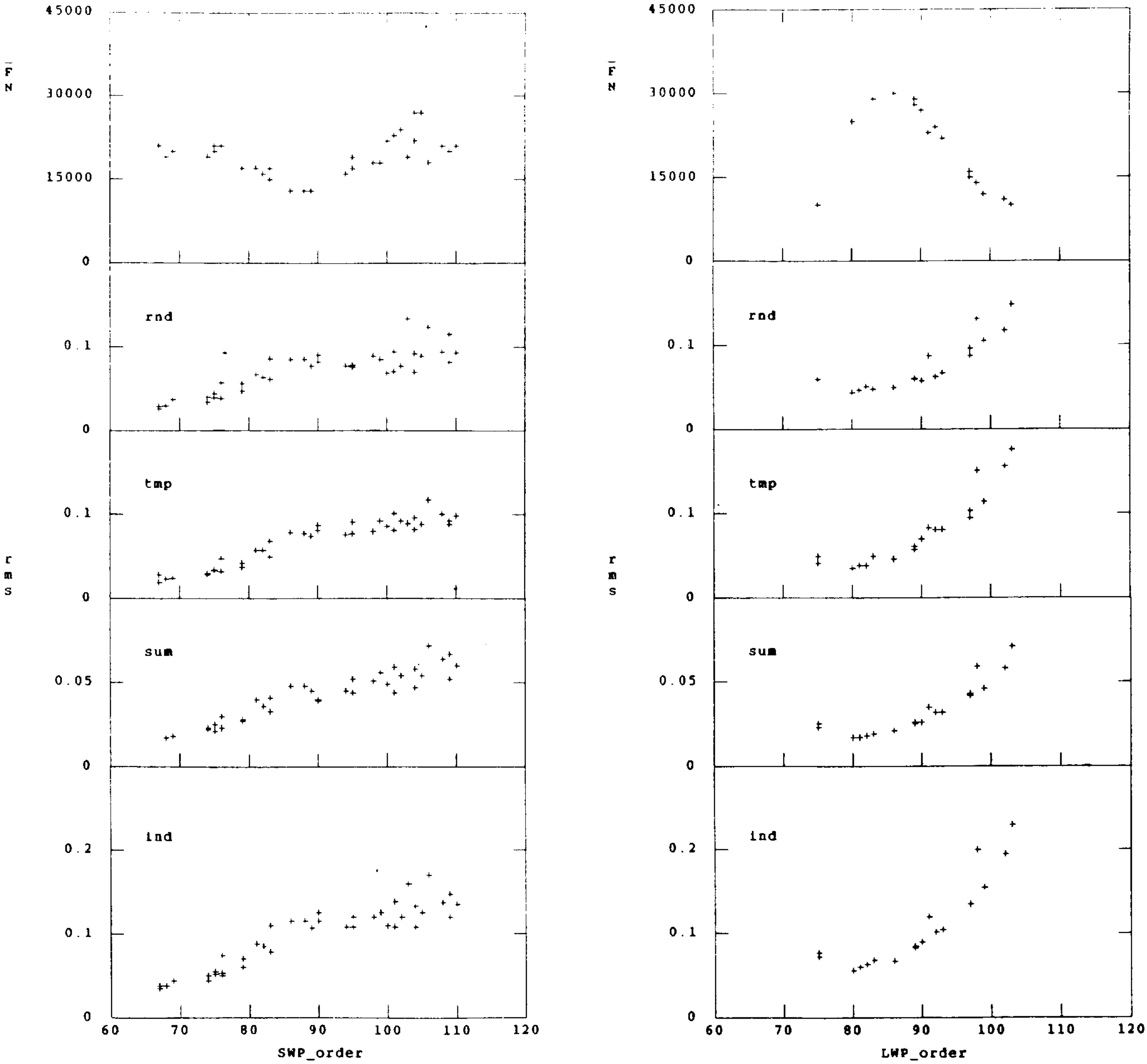

Figure 1. Noise characteristics of various regions of SWP (left) and LWP (right) cameras as functions of order number. From bottom to top: typical individual spectrum (ind), sum of 15 spectra (sum), template spectrum (tmp), and computed random noise in individual spectrum (rnd). At the top is the mean net flux.

Table 1 - Noise in templates (old and new ITFs)

SWP	$\lambda_1 - \lambda_2$	npts	ind	sum	div	tmp	rnd	FN
68	2023-2032	244	.038	.017	.008	.023	.030	19000
			.038	.016	----	.024	.029	
74	1860-1869	265	.050	.022	.009	.030	.040	19000
			.050	.021	.008	.028	.041	
79	1739-1748	280	.060	.027	.010	.037	.047	17000
			.059	.024	.010	.034	.048	
82	1670-1679	276	.085	.036	----	.057	.063	16000
			.081	.034	.015	.050	.064	
99	1391-1398	274	.125	.056	----	.092	.085	17000
			.122	.053	.019	.084	.088	

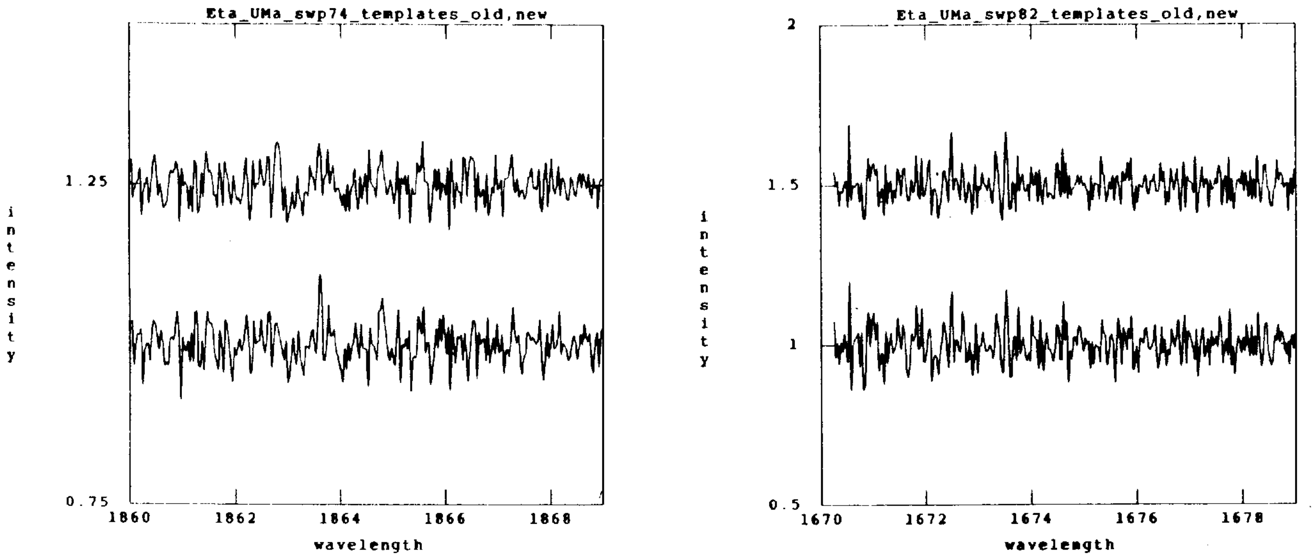

Figure 2. Representative comparisons for SWP orders 74 (left) and 82 (right) between templates constructed from 15 η UMa spectra processed with the old (bottom) and new (top) ITFs.