A CORRECTION METHOD FOR THE DEGRADATION OF THE LWR CAMERA (II) : ERRATUM AND FINAL RESULTS.

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1. Introduction

In Paper I (Clavel,Gilmozzi & Prieto 1985), we published an analysis of the degradation of the IUE LWR camera from 1978 up to 1983, and proposed a simple algorithm to correct for this effect. Later, Imhoff (1986) compared our correction method with that of Holm (1985) and concluded that both techniques yielded reasonable results.

Following the recomendations made at a previous 3-Agency meeting, we performed various checks of the correction method and, in the process, we discovered an error which significantly alters our previous results.

The whole analysis was performed again and yielded a revised curve of the loss of sensitivity of the LWR camera as a function of wavelength. In the present note, we describe the new results, and investigate possible systematic effects which could possibly affect them. We also go through extensive checks of the correction method.

2. The error

Beside long term changes, the sensitivity of the IUE cameras depends primarily on the temperature of their head-amplifier (THDA) at the time of the observation. Any study of the degradation of the camera should therefore correct for this effect by <u>dividing</u> the flux by:

$$E(THDA) = 1.0 - 0.011 * (THDA - 12)$$

as we stated correctly in Paper I. However, we discovered that the computer code was actually doing the opposite, i.e. <u>multiplied</u> by E(THDA).

In principle, this should have simply increased the scatter in the results without drastically changing the trends. Unfortunately, like the temperature of most other subsystems, the average THDA increases as the S/C ages. This is illustrated in figure 1 where we plot the THDA versus the time of observation t (expressed as days after launch) for the 308 spectra of the 5 IUE calibration stars which form the data-base used in the present study. The usual statistical tests show that THDA is linearly correlated with t at better than the 99.9 % confidence level. The slope of the best-fit regression line yields an increase of 0.30 ± 0.14 C/year which translates into a decrease in sensitivity of 0.33 % per year. This agrees reasonably well with the finding by Schiffer (1982) that THDA increases by 0.6 C/year given our longer time base-line.

Therefore, we expect the results of Paper I to overestimate the loss of sensitivity of the LWR camera by twice that amount, i.e. 0.67 % per year.

3. The revised degradation curve

Having properly corrected the spectra for THDA, we have performed the whole analysis again. The method and the data-base were identical to those described in Paper I:
We have used all (308) the low resolution LWR Net spectra of the 5 IUE standard stars which (i) had a "nominal" exposure time (ii) had been obtained through the large aperture (iii) were neither "trailed" nor multiple.
All the spectra had been processed (or re-processed when necessary) with the current low-dispersion S/W.
The Net fluxes were divided by the exposure times – taking into account the OBC timing as well as the camera rise-time (Paper I) – and averaged in bins 50 A wide from 1850 A to 3300 A.
For each star separately and each wavelength bin, we performed a linear regression which yielded the net count-rate as a function of time. The 5 separate data-set were then normalized so that the count rate at launch time is one, prior to being merged. A second regression and renormalization was performed on the combined data-set. The best-fit coefficients of the final regression yielded the rate of sensitivity loss of the LWR camera (in % per year) as a function of wavelength, D1(λ) listed in Table 1. The D1(λ) curve is

plotted in figure 2, together with the wrong curve of Paper I, Dw(λ).

4. Quality control

4.a THDA

The difference between the two curves averaged over the 28 wavelength bins is 0.67 %, exactly as expected (see section 2). Also as expected, this difference is almost independent of wavelength (r.m.s. scatter is 0.16 %) since the effect of THDA variation on the sensitivity is supposedly "grey".

As a check, we have performed the same analysis as described in section 3, but without correcting the spectra for the effect of THDA. This yielded a different Do(λ) curve which is also plotted in figure 2. As expected, Do falls exactly at midway in between the erroneous Dw(λ) of Paper I and the properly THDA corrected D1(λ) curve.

4.b Reality of the structure in the D1(λ) curve.

To check the reality of the structure in the D1(λ) curve, we have shifted our initial wavelength grid by 25 A (without changing the bin size) and performed the same analysis again. The corresponding D2(λ) curve is shown in figure 3 together with D1(λ). The two have been merged in Table 1 to form a unique and final curve of the sensitivity loss which will hereinafter be referred to as D(λ). For illustration purposes, we show in figure 4, the individual D(λ) curves as derived independently for each of the 5 stars.

As it can be seen, the D1 and D2 curves agree fairly well. Most of the structure is therefore real; in particular, the broad hump centered at 2325 A, the secondary maximum near 2775 A and the steep rise shortward of 1900 A. The deep narrow minimum near 2475 and the small peak near 2075 A are possibly real as well, since they are found in the individual D(λ) curves of each star. The remaining features of the D(λ) curve – in particular the large fluctuations at the long wavelength end – are spurious.

4.c Checks of the correction procedure

We have then checked that the correction procedure described in Paper I works properly and removes the effect of the sensitivity loss of the LWR camera.

We have selected 55 spectra (11 for each of the 5 stars) with sequential numbers in the range ~ 14000 to 17000. These are listed in Table 2, together with their epoch of acquisition, exposure time and THDA.
These spectra were corrected for THDA and exposure times as described in section 2 and 3, rebined in steps of 5 A from 1900 to 3200 A and then divided by

$$1 - D(\lambda)*(t - 1978.8)$$

to correct for the sensitivity loss. A linear interpolation was used to bring the $D(\lambda)$ curve onto the same wavelength grid as the spectra.

Following Imhoff (1986), we have then ratioed these 55 corrected spectra to the IUE fluxes of the 5 IUE standard stars as given by Bohlin (1986). To be consistent, we have calibrated the spectra with the revised Bohlin (1986) IUE flux-scale, so that the ratios are independent of the adopted calibration. The mean ratio as a function of wavelength, $R(\lambda)$, is shown in figure 5. Its average value each 50 A (and r.m.s. deviation) is listed in table 3. The mean value of $R(\lambda)$ averaged over the entire 1900-3200 A range is 0.999 ± 0.052. As can be judged, the correction procedure works fairly well. The departures of $R(\lambda)$ from one are well within the error bars and also within the residual uncertainty in the IUE calibration.

In Paper I, we compared a single "corrected" spectrum (LWR13623 - THDA = 14.8) with a single reference spectrum (LWR2225 - THDA = 9.2) of BD+28 4211. Since we applied to both spectra the erroneous THDA correction (section 2) which almost perfectly compensated for the overestimated sensitivity loss, the error was not detected.

4.d Non applicability of the method for recent spectra

We retrieved from the data-bank 8 of the 9 recent spectra that Imhoff used (the 9th one was not yet available at Vilspa) in her study, and we perform the same analysis as in 4.c. The mean ratio for these 8 spectra is shown in figure 6. It is clear that the revised correction curve does <u>not</u> apply to these spectra which had all been acquired after October 1983, i.e. when the LWR camera was no longer routinely used. It is therefore likely that the rate of sensitivity loss increased after the camera was switched-off. This change is wavelength dependent, as can be seen in figure 6. It turns-out (by pure coincidence) that the curve of Paper I provides an acceptable correction for these very recent spectra, which explains why Imhoff (1986) did not detect our error.

It is worth noting that the increase in the degradation rate took place predominantly longward of 2300 A, i.e. in that part of the camera format most affected by the development of the flare. Also, it seems that the change did not occur immediately after the camera was turned-off, but came in somewhat later, since some of the spectra used to check the D(λ) curve had been obtained in late 1983 or even early 1984 (see Table 2). This probably accounts for the fact that the increase in the rate of sensitivity loss does not show-up in the quick-look monitoring of Sonneborn (1984). The temporal behaviour of the LWR sensitivity after 1983 is reminiscent of the exponentially increasing flare rate (Harris 1985). It is not clear why the rate of sensitivity loss increased after October 1983. It could be due, for instance, to a change in the characteristics of the detector as it was not routinely used anymore. However, both the spectral and the temporal behaviour of this increase rather suggest that it is linked in some way to the flare itself. More work is obviously needed to get a full understanding of the phenomenon.

References

Bohlin,R.1986,Ap.J. 308 (in press).
Clavel,J.,Gilmozzi,R.,Prieto,A.1985,ESA Newsletter 23,48.
Harris,A.W.1985,Report to the 3 Agencies (April).
Holm,A.1985,NASA Newsletter 26,11.
Imhoff,C.L.1986,NASA Newsletter 29,5.
Schiffer,F.H.1982,NASA Newsletter 19,33.
Sonneborn,G.1984,Report to the 3 Agencies (November).

Table 1

Wavelength (A)	Sensivity loss (% per year)	Wavelength (A)	Sensivity loss (% per year)
1850.000	3.790 ± .510	2575.000	.880 ± .110
1875.000	2.150 ± .340	2600.000	.940 ± .120
1900.000	1.790 ± .220	2625.000	.820 ± .090
1925.000	1.510 ± .180	2650.000	.650 ± .090
1950.000	1.560 ± .150	2675.000	1.140 ± .090
1975.000	1.730 ± .150	2700.000	1.130 ± .080
2000.000	1.620 ± .100	2725.000	.740 ± .080
2025.000	1.510 ± .100	2750.000	1.180 ± .090
2050.000	1.860 ± .100	2775.000	1.710 ± .100
2075.000	2.170 ± .110	2800.000	1.600 ± .100
2100.000	1.750 ± .110	2825.000	1.220 ± .090
2125.000	1.410 ± .130	2850.000	1.420 ± .080
2150.000	1.480 ± .090	2875.000	1.220 ± .090
2175.000	2.020 ± .130	2900.000	.980 ± .090
2200.000	2.270 ± .120	2925.000	.880 ± .090
2225.000	2.240 ± .110	2950.000	.940 ± .090
2250.000	2.400 ± .100	2975.000	.840 ± .100
2275.000	2.670 ± .110	3000.000	.830 ± .110
2300.000	2.850 ± .100	3025.000	1.320 ± .130
2325.000	2.900 ± .110	3050.000	1.160 ± .140
2350.000	2.880 ± .090	3075.000	.590 ± .150
2375.000	2.610 ± .100	3100.000	1.030 ± .130
2400.000	1.680 ± .090	3125.000	1.220 ± .170
2425.000	1.710 ± .090	3150.000	.560 ± .190
2450.000	1.510 ± .090	3175.000	1.290 ± .370
2475.000	.720 ± .090	3200.000	2.810 ± .610
2500.000	.980 ± .090	3225.000	1.320 ± .480
2525.000	1.400 ± .090	3250.000	1.020 ± .450
2550.000	1.040 ± .100	3275.000	3.010 ± .660

Table 2

List of spectra used to test the correction method and generate the ratio spectrum of figure 5. Exposure times are nominal: 190 s, 3 s, 7 s, 24 s & 60 s for BD+33 2642, HD93521, HD60753, BD+75 325 & BD+28 4211 respectively. Dates are written as "yymmdd", where yy are the 2 last digits of the year, mm is the month, and dd is the day of the month. THDA is in Celsius degree.

LWR #	Star	THDA	date	LWR #	Star	THDA	date
15073	BD+33 2642	16.0	830119	16243	HD 60753	14.2	830626
15219		15.2	830209	16287		12.8	830703
15445		14.9	830308	16589		14.5	830814
15847		13.2	830430	16907		15.9	831001
15889		15.2	830507	16947		12.2	831008
16292		10.8	830704	14936	BD+75325	14.8	821227
16403		13.8	830721	15362		14.5	830223
16619		15.2	830818	15685		13.2	830409
17183		13.7	831216	15733		13.8	830414
17204		14.2	840101	15891		15.5	830507
17246		15.0	840213	16564		14.5	830810
14472	HD 93521	14.2	821024	16714		15.5	830901
14594		13.8	821110	16759		12.2	830909
14974		16.5	830101	16824		12.2	830918
15363		14.5	830224	16905		15.9	831001
15446		15.2	830308	17170		13.5	831129
15626		16.5	830331	14165	BD+28 4211	11.5	820913
15684		13.0	830409	14166		11.8	820913
15966		14.5	830518	14542		14.2	821101
16289		12.7	830703	14887		14.8	821224
17169		13.5	831129	14935		14.5	821227
17205		14.2	840101	15071		16.2	830119
14245	HD 60753	11.5	820924	15077		14.5	830119
14593		13.8	821110	16146		13.5	830613
14774		12.2	821203	16241		14.8	830625
15218		15.2	830209	16268		12.8	830630
15849		13.2	830430	16269		13.5	830701
16082		14.5	830606				

Table 3:

Mean ratio spectrum of the 55 spectra listed in table 2 to the flux of the IUE standard stars in Bohlin (1986). The spectra have been corrected for the sensitivity loss of the LWR camera as described in the text. The average flux of the mean ratio spectrum (figure 5) and the r.m.s. deviation in 50 Å bins have been computed from 1900 to 3200 Å.

Bin (Å)	aver. ± r.m.s	Bin (Å)	aver. ± r.m.s
1900–1950	0.994 ± 0.057	2550–2600	1.007 ± 0.044
1950–2000	0.968 ± 0.048	2600–2650	1.011 ± 0.029
2000–2050	0.995 ± 0.045	2650–2700	0.993 ± 0.032
2050–2100	1.015 ± 0.043	2700–2750	1.012 ± 0.030
2100–2150	1.010 ± 0.059	2750–2800	1.017 ± 0.036
2150–2200	0.975 ± 0.035	2800–2850	1.013 ± 0.029
2200–2250	0.998 ± 0.052	2850–2900	1.014 ± 0.033
2250–2300	0.989 ± 0.036	2900–2950	0.994 ± 0.052
2300–2350	0.988 ± 0.030	2950–3000	0.993 ± 0.039
2350–2400	0.986 ± 0.049	3000–3050	0.987 ± 0.052
2400–2450	0.975 ± 0.030	3050–3100	0.993 ± 0.091
2450–2500	0.994 ± 0.046	3100–3150	0.990 ± 0.071
2500–2550	0.998 ± 0.040	3150–3200	1.024 ± 0.111

Figure captions

Figure 1:

The temperature of the LWR camera head-amplifier (THDA) versus time (expressed as days after launch) fot the 308 spectra used in the present study.

Figure 2:

The revised D1(λ) curve of sensivity loss (% per year)as a function of wavelength, together with the erroneous curve of Paper I (*) and the one obtained without applying any THDA correction (o).

Figure 3:

The combined D(λ) curve of sensivity loss as a function of wavelength, obtained by merging the D1(λ) (*) and D2(λ) (o) curves. The D2 curve uses the same bin size of 50 A as the D1 curve but is shifted by +25 A as explained in the text.

Figure 4:

The individual curve of sensivity loss for each of the 5 standard stars plotted with different symbols and no error bars for clarity: BD+28 4211 (*), BD+33 2642 (+), BD+75 325 (o), HD60753 (#) and HD93521 ($).

Figure 5:

The average ratio of the 55 spectra listed in table 2 to the flux of the 5 IUE standard stars as given by Bohlin (1986) The spectra have been corrected for the sensitivity loss of the LWR camera as explained in the text. The unity line is shown for comparison.

Figure 6:

Similar ratio as in figure 5, but for 8 more recent spectra (listed in Imhoff 1986). The ratio spectrum clearly deviates from unity, especially longward of 2300 A.

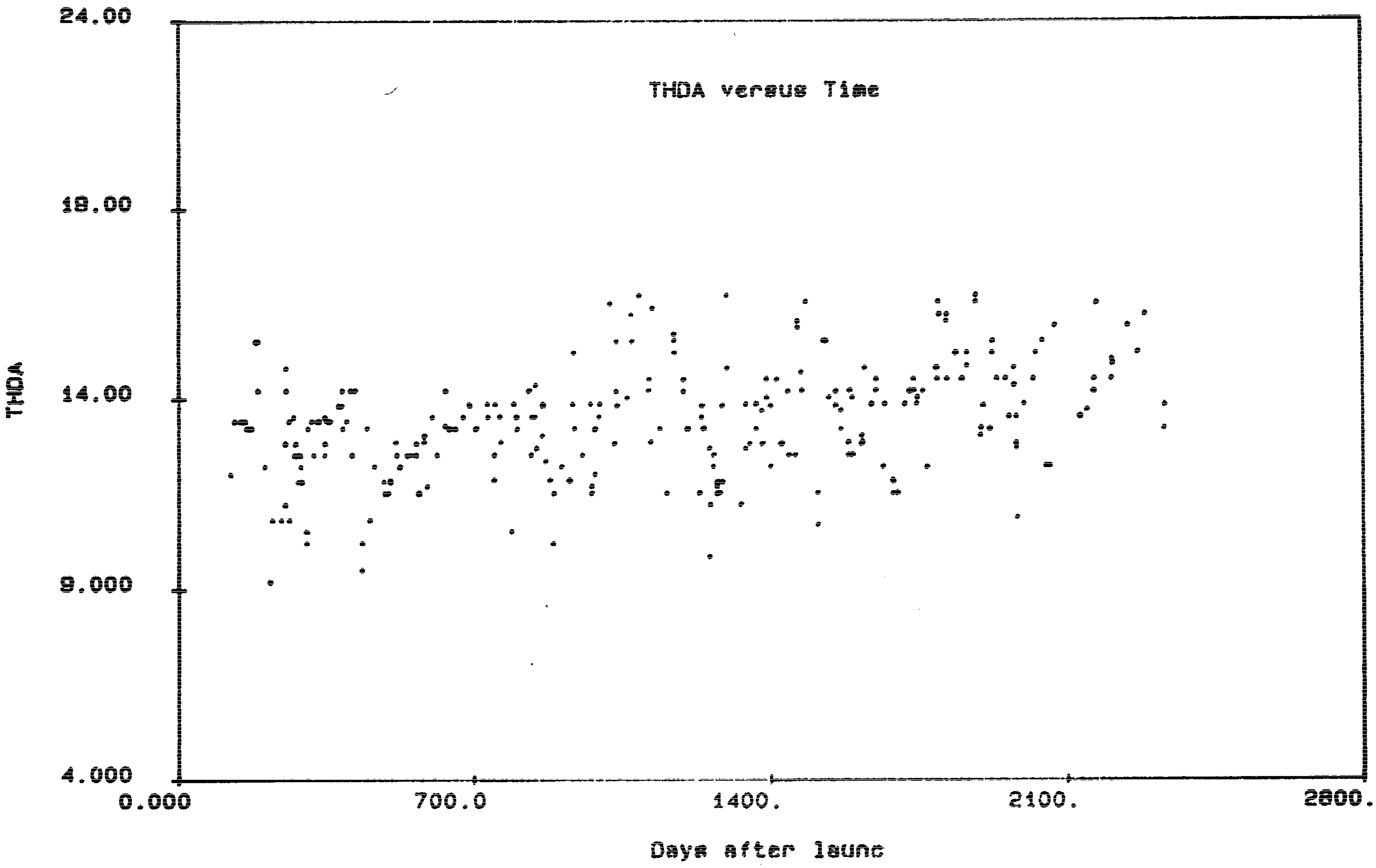
THDA versus Time
THDA
24.00
18.00
14.00
9.000
4.000
0.000
700.0
1400.
2100.
2800.
Days after launc

Figure 1

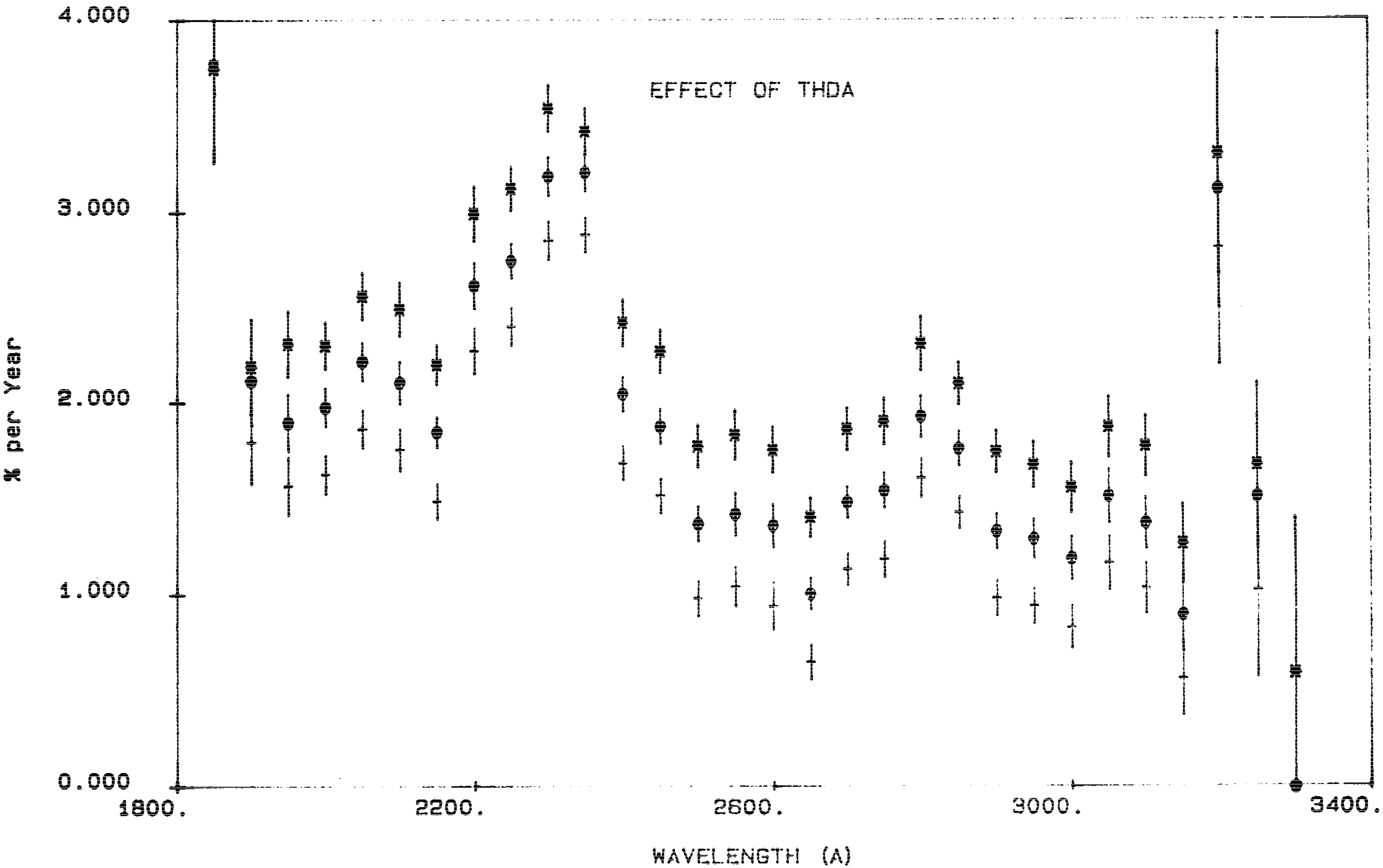
EFFECT OF THDA
% per Year
4.000
3.000
2.000
1.000
0.000
1800.
2200.
2600.
3000.
3400.
WAVELENGTH (A)

Figure 2

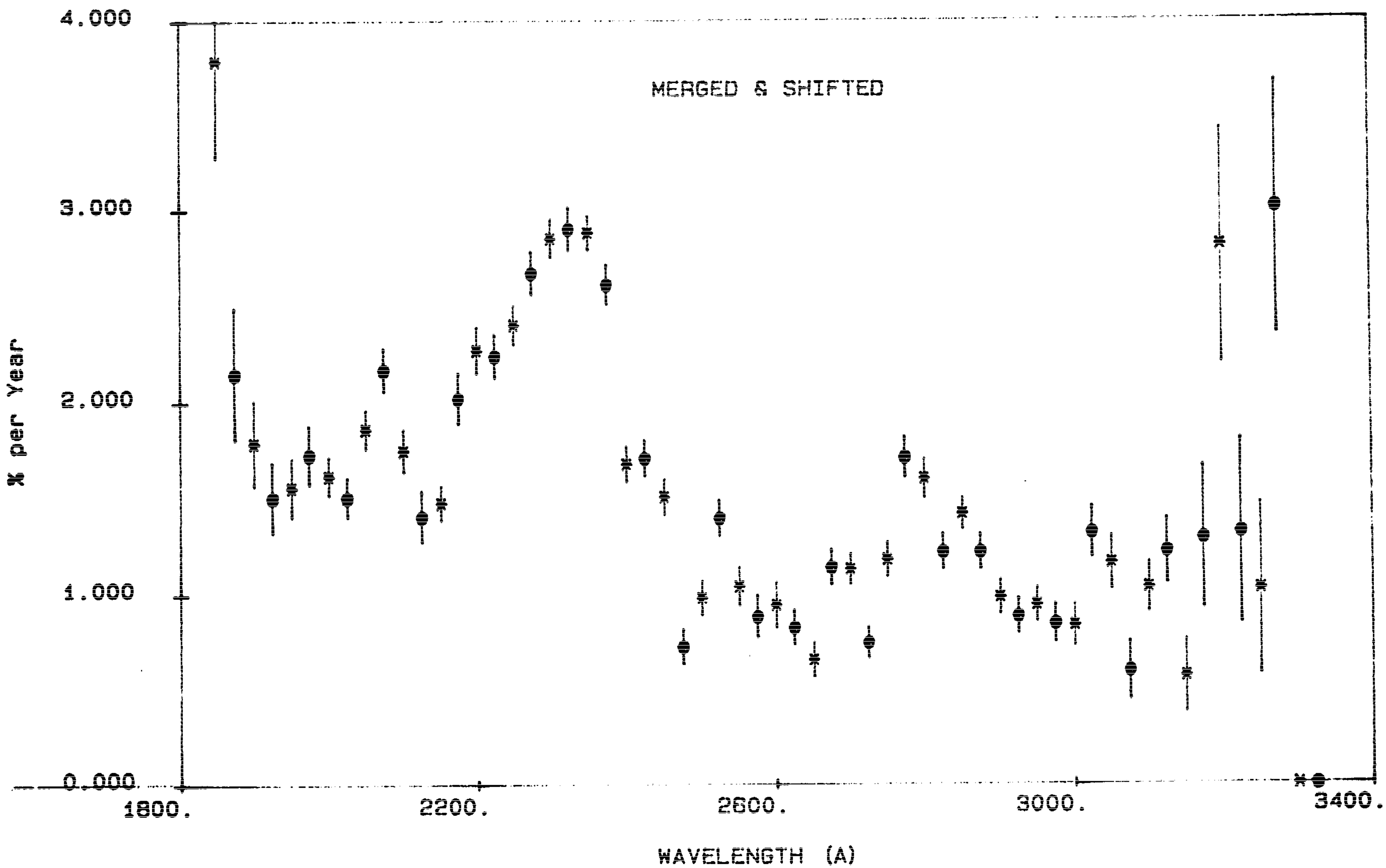
MERGED & SHIFTED
% per Year
4.000
3.000
2.000
1.000
0.000
1800.
2200.
2600.
3000.
3400.
WAVELENGTH (A)

Figure 3

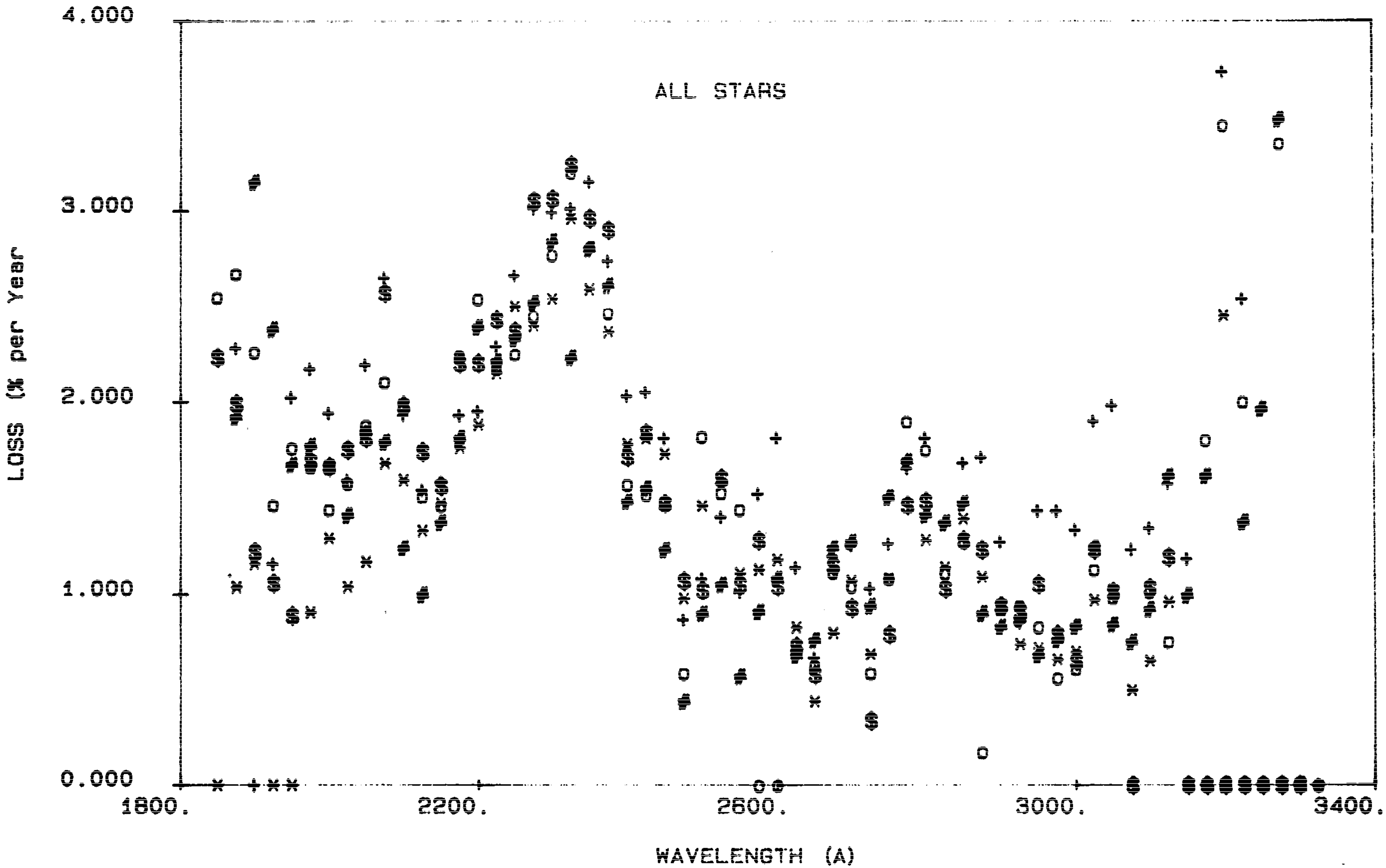
ALL STARS
LOSS (% per Year)
4.000
3.000
2.000
1.000
0.000
1800.
2200.
2600.
3000.
3400.
WAVELENGTH (A)

Figure 4

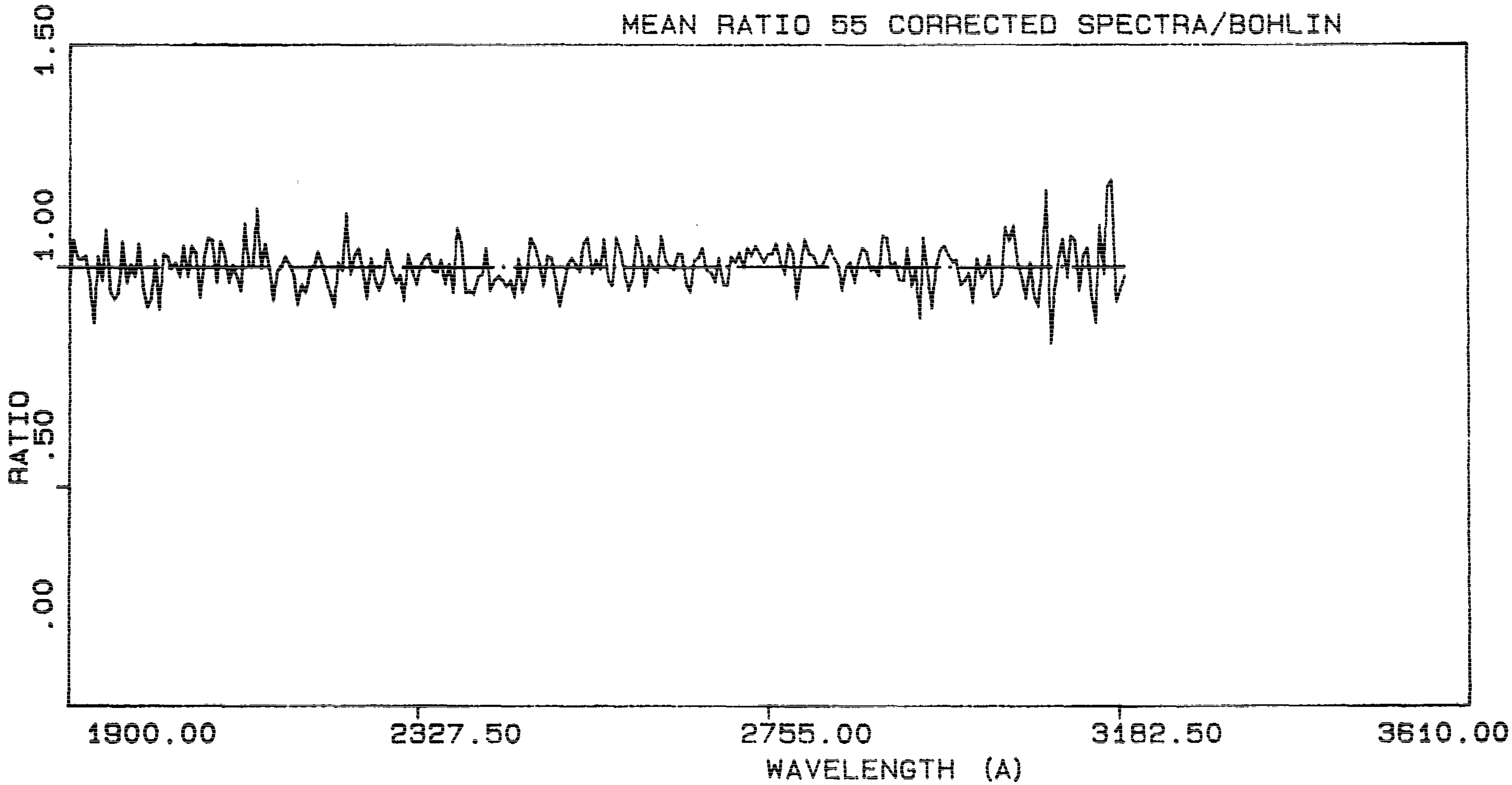
MEAN RATIO 55 CORRECTED SPECTRA/BOHLIN
RATIO
1.50
1.00
.50
.00
1900.00
2327.50
2755.00
3182.50
3610.00
WAVELENGTH (A)

Figure 5

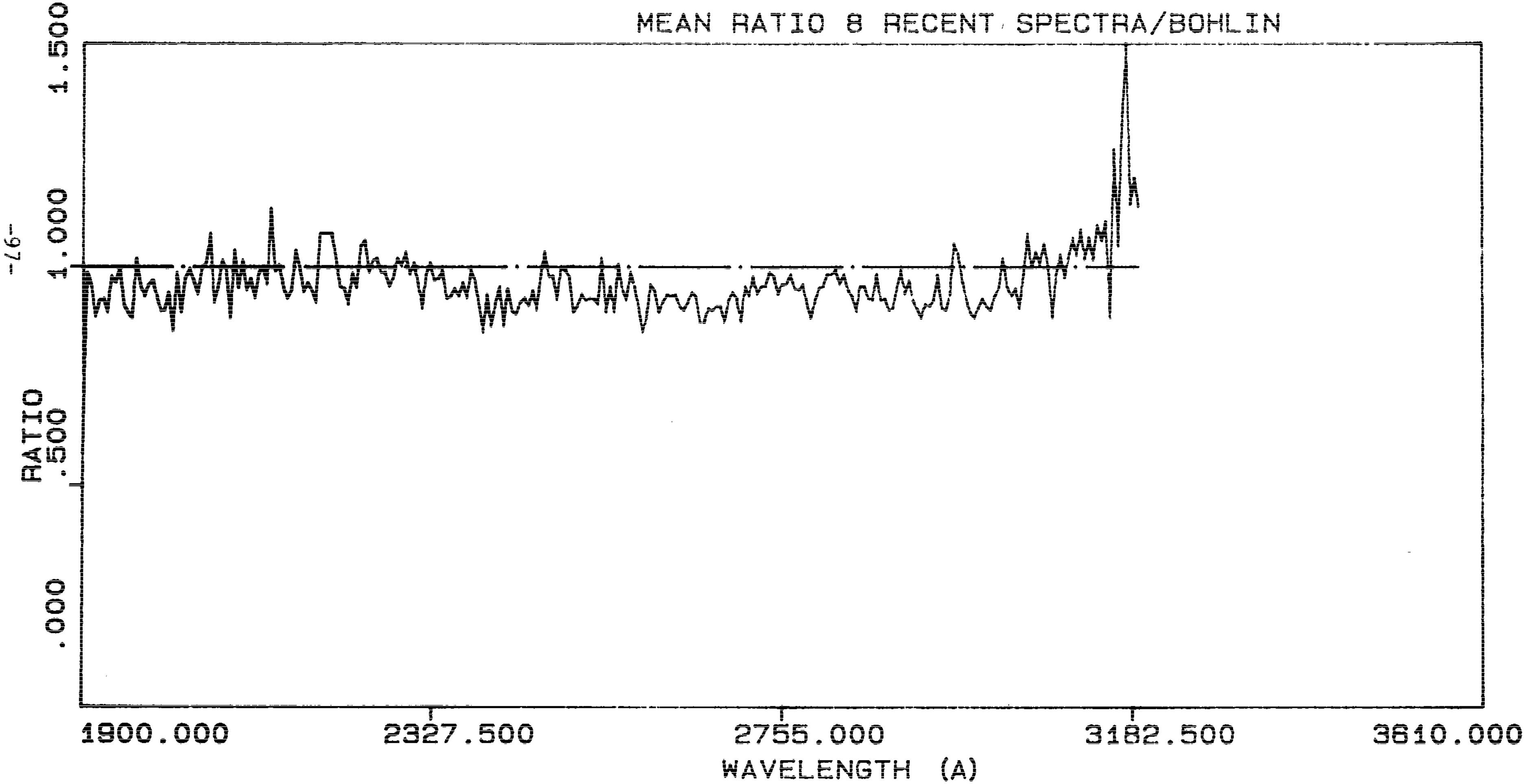
MEAN RATIO 8 RECENT SPECTRA/BOHLIN
RATIO
1.500
1.000
.500
.000
1900.000
2327.500
2755.000
3182.500
3610.000
WAVELENGTH (A)

Figure 6