AN ANALYSIS OF THE PERFORMANCE OF TWO LWR DEGRADATION CORRECTION METHODS

Catherine L. Imhoff
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Abstract: An analysis was performed using 9 recent spectra of IUE calibration stars to determine the accuracy with which LWR spectra may be corrected for sensitivity degradation. Two methods, by Holm and by Clavel, Gilmozzi, and Prieto, work reasonably well. For spectra obtained in 1985, after the LWR camera was no longer routinely in use, some systematic errors are seen. Holm's algorithm tends to undercorrect by 3%, while Clavel et al.'s method overcorrects by only 0.5%. The RMS errors for the ratio of the corrected data to the original calibration fluxes, given in 10 A bins, are about 6 to 7%. Both methods overcorrect somewhat around the region of maximum sensitivity degradation and at long wavelengths. Additional analysis is needed to determine whether these results, which apply to recent LWR data obtained after the Holm and Clavel et al. analyses were performed, can be applied to earlier data.

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Two studies which provide methods to correct LWR data for sensitivity degradation have recently been published in this newsletter. Such algorithms have been neccesary because the sensitivity of the camera has decreased by over 10 % at most wavelengths and as much as 25 % around 2300 A since the original epoch of the calibration. The correction methods are intended to allow one to scale the data back to the original calibration (epoch 1978.8). The purpose of this paper is to examine how well these two methods succeed in correcting low-dispersion LWR spectra for sensitivity degradtion.

Holm (1985) analyzed LWR spectra of stars obtained for the original calibration in late 1978 - early 1979 and additional spectra obtained during 1983. These included large aperture, trailed, and small aperture spectra as used in the original calibration. He corrected for various sources of systematic errors, including extraction and wavelength errors in the early data, camera exposure time quantization and response time, thermally-induced changes in camera sensitivity, and the effects of microphonic noise. The ratios of the early spectra and late spectra for the various stars then characterized the sensitivity changes between the two epochs. This approach preserved the wavelength resolution of the results but, because a limited number of spectra were involved, the ratios were noisy. He therefore fitted a smooth curve to the degradation results. His results were presented in units of magnitudes per year.

Clavel, Gilmozzi, and Prieto (1985) employed a different approach. They retrieved all the available LWR spectra from 1978 through late 1983 for the 5 calibration stars used to monitor sensitivity changes. Early data were reprocessed, removing the extraction and wavelength errors present. They also corrected for the camera exposure time quantization and response time, thermally-induced sensitivity changes, and microphonic noise. Only point-source spectra taken through the large aperture were used. A total of 308 spectra were employed in the analysis. The spectra, in units of Flux Number per second, were binned into 50 A bins, as used for the original absolute calibration. After normalization and combination of the results for all 5 stars, a linear regression versus time was performed. Their results were presented in units of percent per year.

Both methods indicate that the greatest sensitivity degradation occurs around 2300 A. Aside from that region, the shorter wavelength regions generally suffer greater degradation with time than the long wavelength portion of the spectrum.

For this analysis 9 recent LWR spectra were chosen, 3 each for 3 calibration stars. The journal of spectra is given in Table 1. Each spectrum was reduced in 3 different ways. In each case, corrections for camera exposure time quantization and response time, thermally-induced sensitivity changes, and microphonics noise were performed. The spectra were trimmed to the wavelength range of 1900 to 3200 A, the limits of the Holm algorithm, before comparison.

(1) The standard reduction was performed using the RDAF routine IUELO, with no corrections for degradation. The spectra were interpolated to a common wavelength scale and averaged.

(2) The standard reduction was performed, followed by application of Holm's algorithm. An experimental routine, called DEGRAD, was used to apply the correction to the data. The spectra were similarly averaged.

(3) A special reduction was performed, in which the degradation corrections computed from Clavel et al.'s results were applied to the absolute calibration, analogous to "correcting" the absolute calibration scale. These values were then interpolated and applied to the net spectra. The spectra were similarly averaged.

Correct IUE fluxes are needed for the 3 stars to provide the standard against which the comparison may be performed. Bohlin (1986) has rederived the fluxes for 5 low-dispersion calibration stars used in the original IUE absolute calibration. He has reanalyzed the spectra, taking into account various sources of error not known at the time of the original calibration. In particular, he has determined and taken into account the systematic differences between small aperture, large aperture, and trailed spectra. This results in a redefinition of the IUE absolute calibration, for which most changes are fairly small. This new absolute calibration does not directly relate to the LWR degradation problem, except that we have used the new fluxes derived by Bohlin for this study. Thus the recent LWR spectra of the 3 calibration stars were reduced using Bohlin's suggested absolute calibration, instead of the standard May 1980 absolute calibration, for consistency. This does not affect the results because only ratios of spectra, in which the absolute calibration applied cancels out, will be discussed.

Figure 1 depicts the LWR fluxes for BD+28 4211. The data have been binned into 10 A bins to reduce noise. The bottom curve represents the new standard fluxes determined by Bohlin (1986). The middle curve depicts the fluxes from the recent spectra after correction for degradation using Holm's algorithm (offset by 2 units). The top curve shows the fluxes from the spectra after correction using Clavel et al.'s results (offset by 4 units). Figures 2 and 3 depict the same set of fluxes for HD 60753 and HD 93521.

The accuracies of the correction algorithms can be examined by ratioing the corrected fluxes to the original calibration fluxes. Figure 4 depicts those ratios for fluxes corrected using Holm's algorithm (middle) and using Clavel et al.'s results (top, offset by 0.4). A line representing perfect agreement is plotted for both ratios. Figures 5 and 6 depict the similar ratios for HD 60753 and HD 93521.

The results for BD+28 4211 indicate that Holm's algorithm appears to undercorrect somewhat, primarily between 2400 and 3100 A. It overcorrects slightly at the long wavelength end and at the region around 2300 A, where the largest sensitivity degradation occurs. The method using Clavel et al.'s results also seems to overcorrect somewhat at the long wavelength end and around 2300 A. The overall shape of the ratios are similar for the two methods. However, the results for Clavel et al.'s corrections indicate a better average result than for Holm's.

Similar results may be seen for the ratios of fluxes for HD 60753 and HD 93521, with some small differences. The means of the ratios for the 3 stars are given in Figure 7. The results described above for BD+28 4211 hold for the averages. The average errors and the RMS errors, for 10 A bins, were computed for the mean ratios derived from both correction methods. These are given in Table 2.

Figure 8 shows the ratios for each of the three stars overplotted. this shows that the results are consistent and do not depend appreciably on the star chosen for the analysis.

Figure 9 shows the mean ratios for the Holm algorithm and Clavel et al. correction overplotted, with the systematic errors removed, to compare the details of the ratios. It is notable that the shapes of the curves are quite similar. Considering that the methods used to derive the LWR degradation are rather different, the similarity in detail between the ratios is surprising. Both methods produce systematically high fluxes around 2300 A, by about 7 %, and near 3200 A, by 15 to 25 %. Elsewhere the agreement is genenerally better than 5 %. The implication of this result is that the errors in the two correction methods as functions of wavelength are quite similar. A possible explanation is related to the epoch of the observations used for this analysis. All the LWR spectra analyzed here are from late 1984 through 1985. Both Holm's and Clavel et al.'s analyses are based on earlier spectra. The spectra used by Clavel et al. were limited to those obtained while the LWR camera was in use as the prime camera (until October 1983). Similarly all but one of Holm's spectra date from before October 1983. Therefore such systematic errors might result if the camera sensitivity degradation changed in nature after the camera was no longer routinely used.

No notable changes are seen in the quick-look sensitivity monitoring results of Sonneborn (1984), using data obtained through 1984.8, but those results are based on 150 A binned data.

It is uncertain how well data obtained at an intermediate epoch might be corrected for degradation. For instance, the results obtained above apply to data obtained 6.5 years after the mean epoch of the original IUE calibration. Are the systematic errors reduced by 1/2 for data obtained 3.25 years ago? Further analysis using spectra obtained in 1981 and 1982 would be required to determine if this were so.

Examples of the application of the two correction methods to LWR spectra are given in Figures 10, 11, and 12. The mean spectrum, generated using three spectra for HD 93521, is depicted. The importance of correcting recent data for degradation is clearly seen. Minor differences occur around 2190 A and 2800 A due to slight variations in patching over the microphonics and the "hot spot" at those wavelengths.

In summary, both Holm's and Clavel et al.'s LWR degradation correction methods work fairly well. For spectra obtained during 1985, Holm's algorithm tends to undercorrect by 3%, with RMS errors of 6%. For the same data, Clavel et al.'s method tends to overcorrect by only 0.5%, with RMS errors of 7%. Both methods seem to overcorrect somewhat around the region of maximum degradation, about 2300 A, and at long wavelengths, longward of 3100 A. The applicability of these results to older data remains to be determined.

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Bohlin, R. 1986, Astrophysical Journal, in press.

Clavel, J., Gilmozzi, R., and Prieto, A. 1985, NASA IUE Newsletter No. 27, pg. 50.

Holm, A. 1985, NASA IUE Newsletter No. 26, pg. 11.

Sonneborn, G. 1984, Report to the Three Agencies (November).

Table 1

LWR Spectra Used in the Analysis

Star	Image Number	Expo Time	Year/Day	THDA
BD+28 4211	17728	60 sec	1985/157	13.8
	17756	60	1985/207	11.8
	17772	60	1985/241	11.5
HD 60753	17494	7	1984/226	12.2
	17699	7	1985/095	14.5
	17768	7	1985/241	10.2
HD 93521	17565	3	1984/356	15.5
	17629	3	1985/051	14.8
	17701	3	1985/095	14.8

Table 2

Average and RMS Errors for LWR Degradation Corrected Spectra in 10 A Bins

Method	Average Error	RMS Error
Holm	-0.0326	0.0624
Clavel et al.	0.0046	0.0711

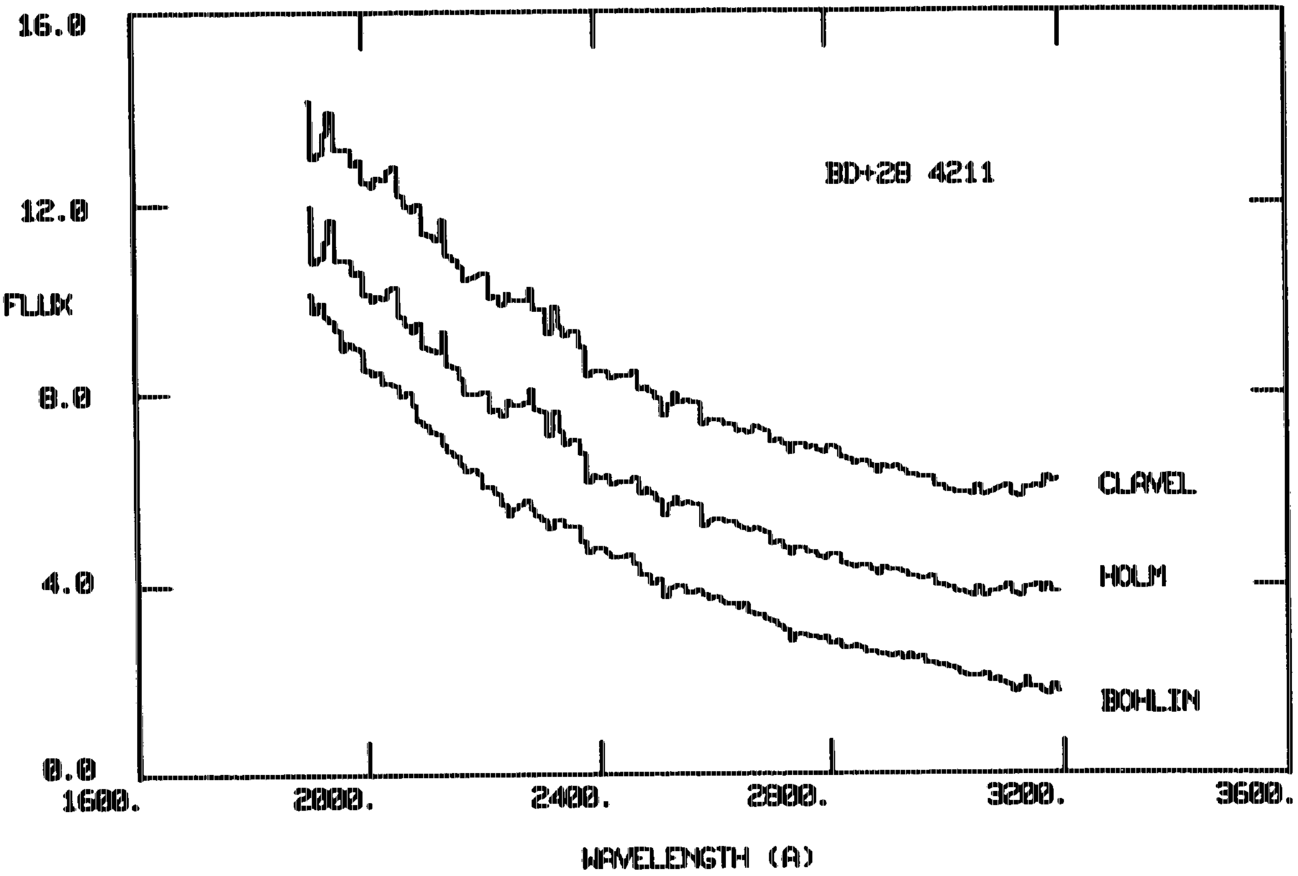

Figure 1. Mean fluxes for BD+28 4211 in 10 A bins determined from 3 LWR spectra. Units are 10^{-12} erg/cm^2/sec. The bottom curve represents the Bohlin calibration fluxes. The middle curve represents the mean spectrum corrected using Holm's algorithm, offset by 2. The top curve represents the mean spectrum corrected using Clavel et al.'s method, offset by 4.

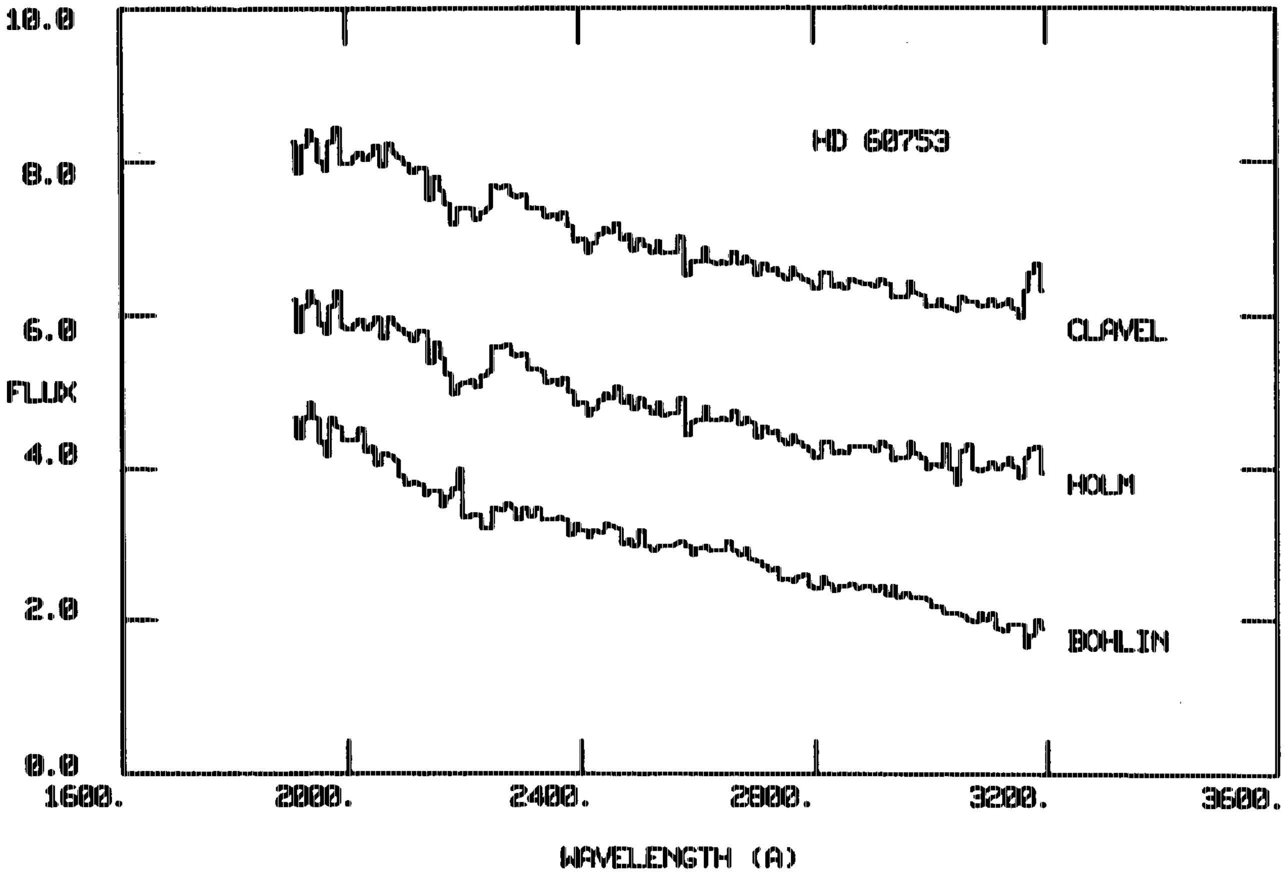

Figure 2. Same as Figure 1, for HD 60753. Units are 10^{-11} erg/cm^2/sec.

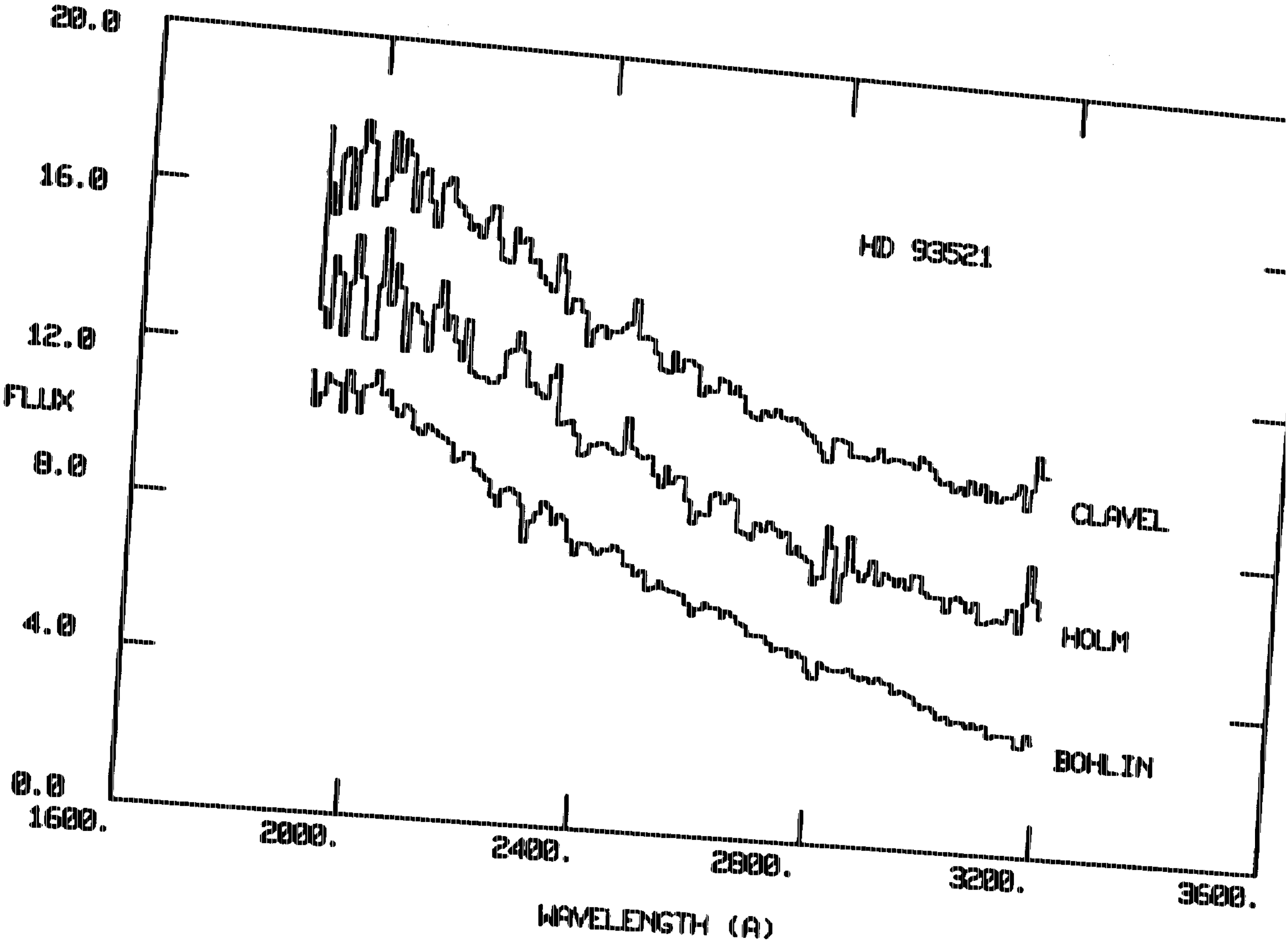

Figure 3. Same as Figure 1, for HD 92531. Units are 10^{-11} erg/cm^2/sec; offsets are 3 and 6.

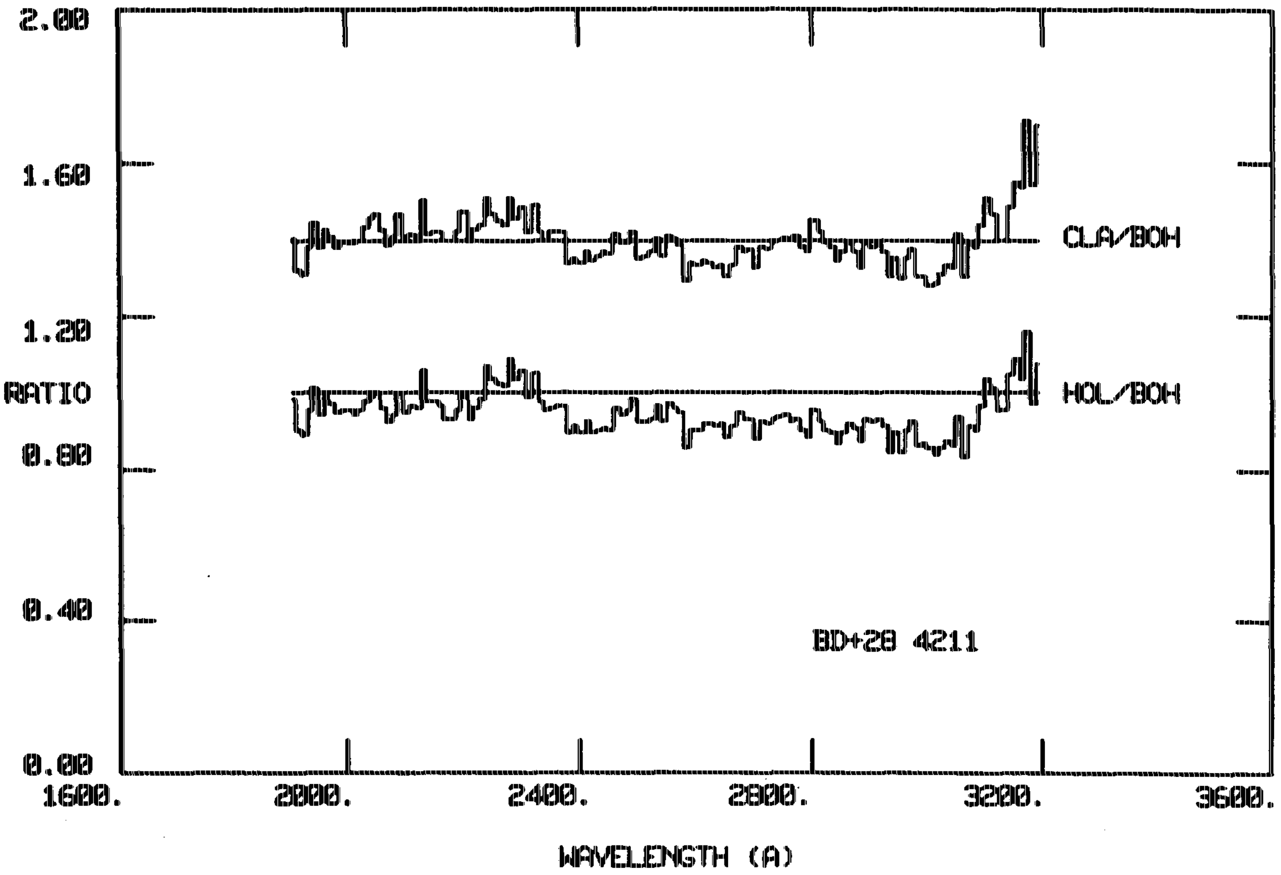

Figure 4. Ratios of mean spectrum of BD+28 4211 corrected by Holm's and by Clavel et al.'s methods with respect to Bohlin's fluxes. The Clavel/Bohlin ratio is offset by 0.4. The straight lines represent ratios of 1.0.

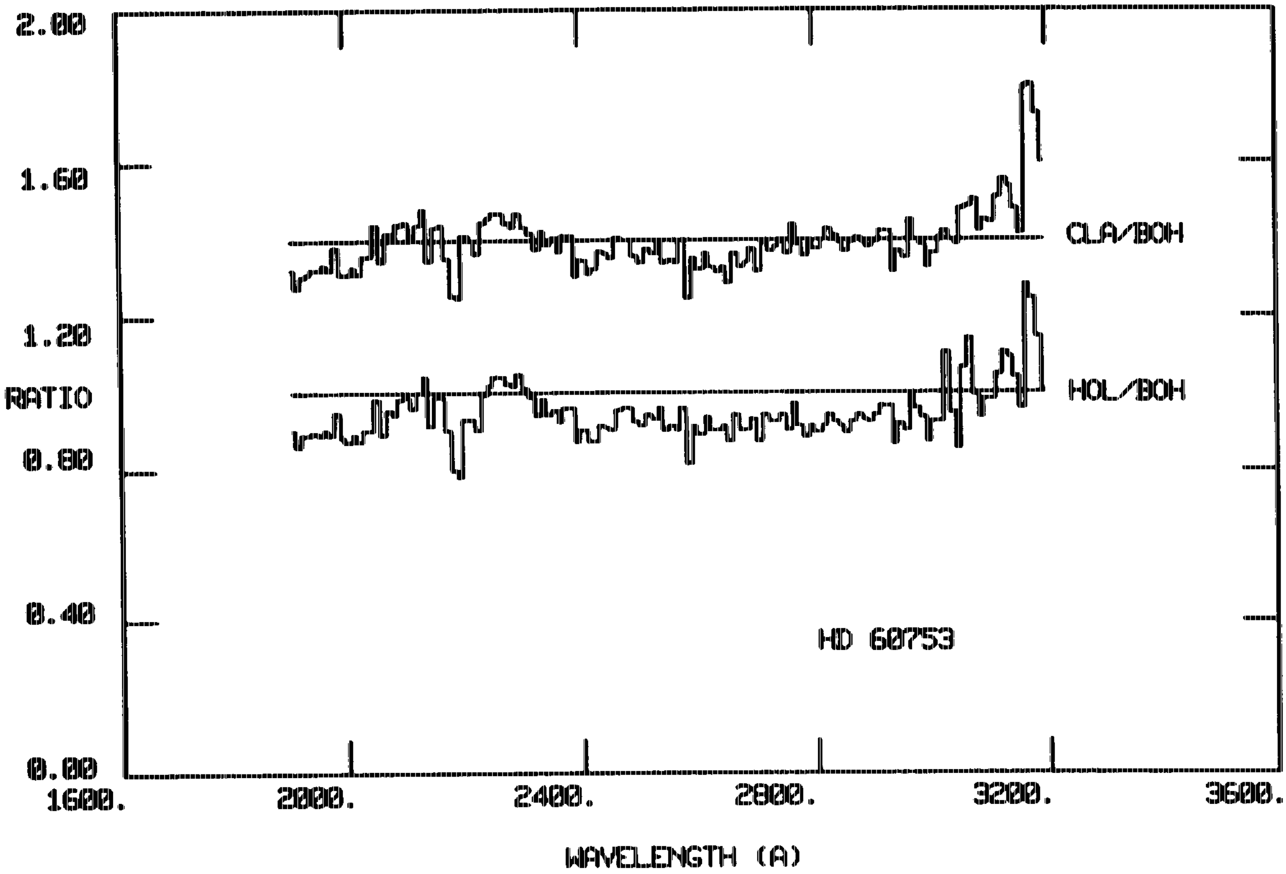

Figure 5. Same as Figure 4, for HD 60753.

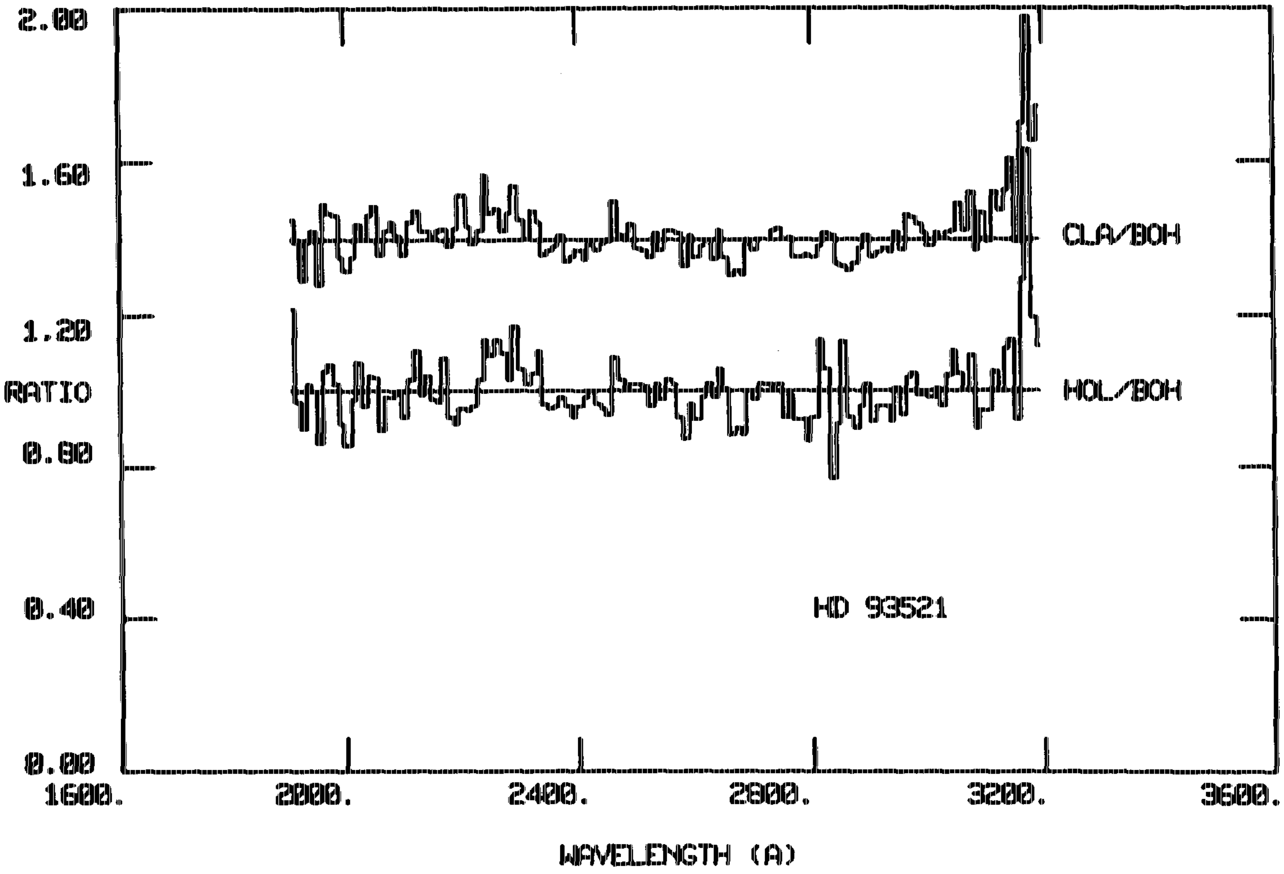

Figure 6. Same as Figure 4, for HD 93521.

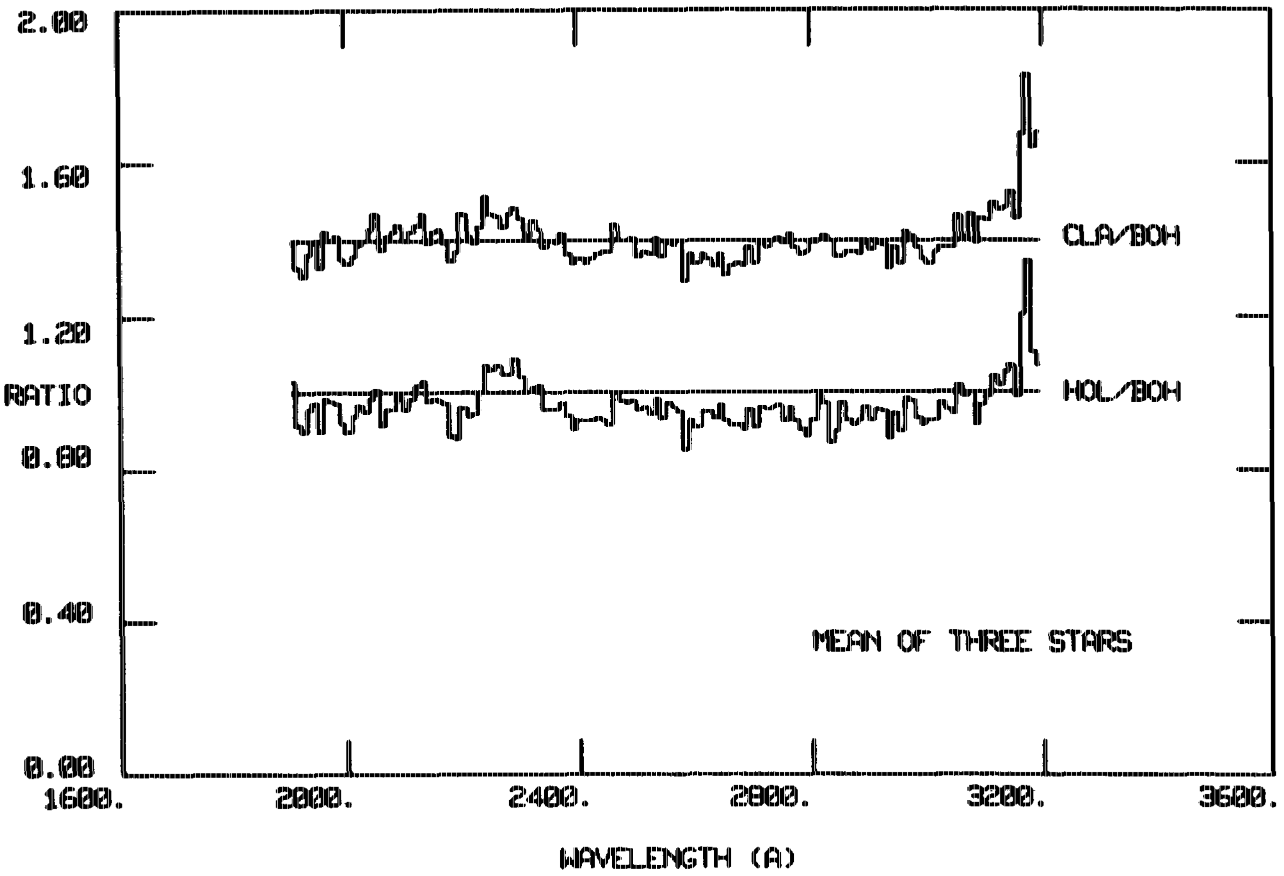

Figure 7. Same as Figure 4, for the mean of the three stars.

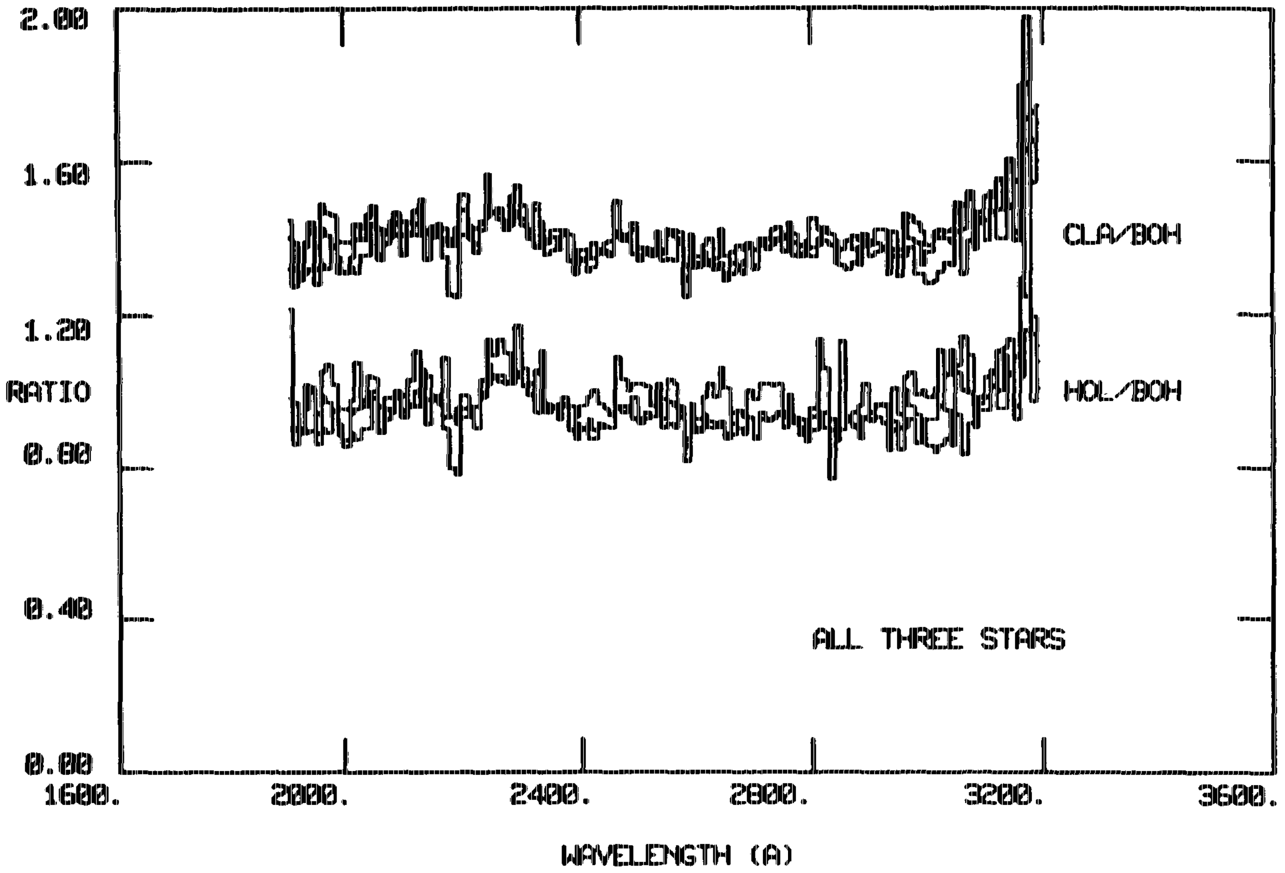

Figure 8. Same as Figure 4, with the ratios for all three stars overplotted.

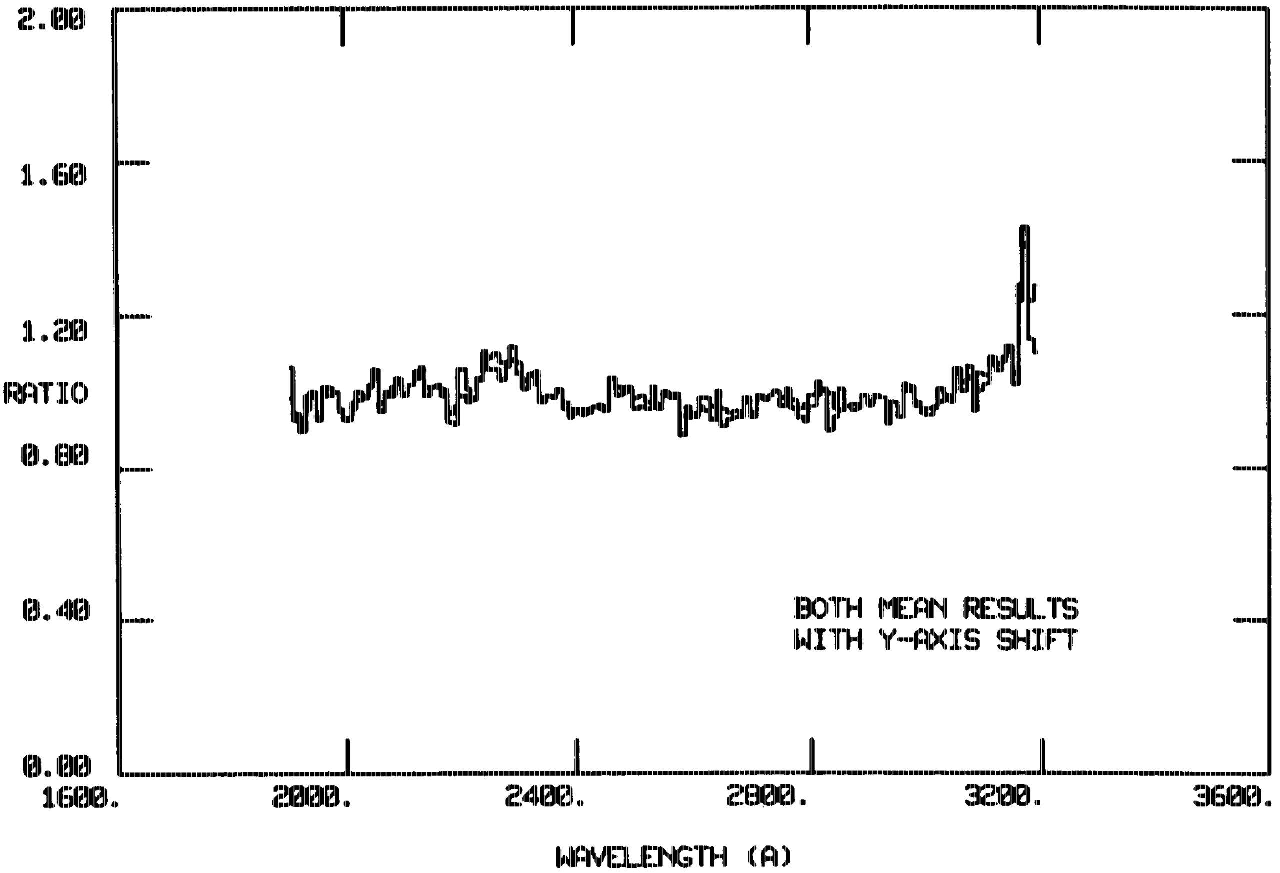

Figure 9. The ratios of the mean spectra corrected by both methods to Bohlin's fluxes, with the average errors removedso that the two curves are overplotted. Note the excellent agreement in the ratios as functions of wavelength.

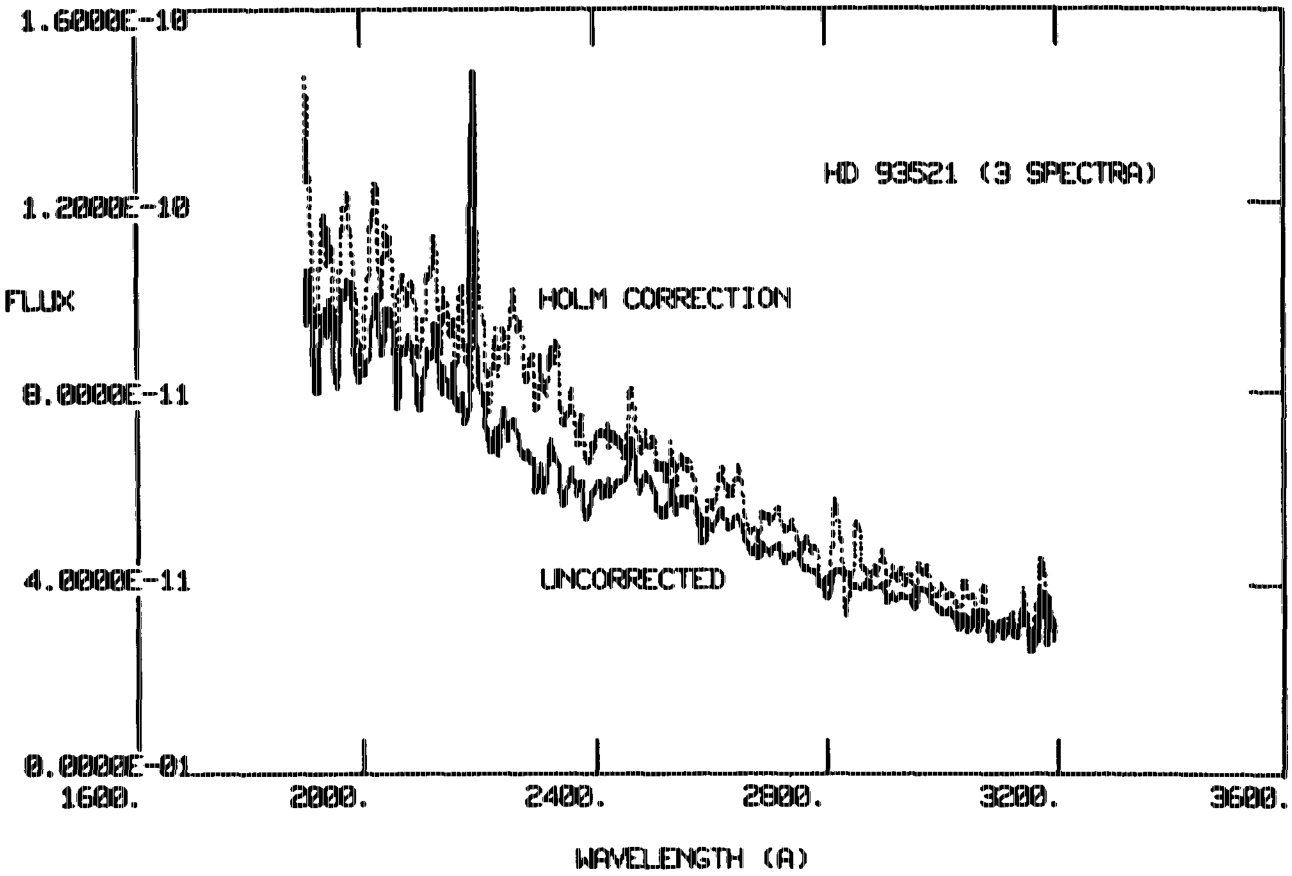

Figure 10. The mean LWR spectrum for HD 93521, uncorrected for degradation (solid line) and corrected using Holm's algorithm (dotted line).

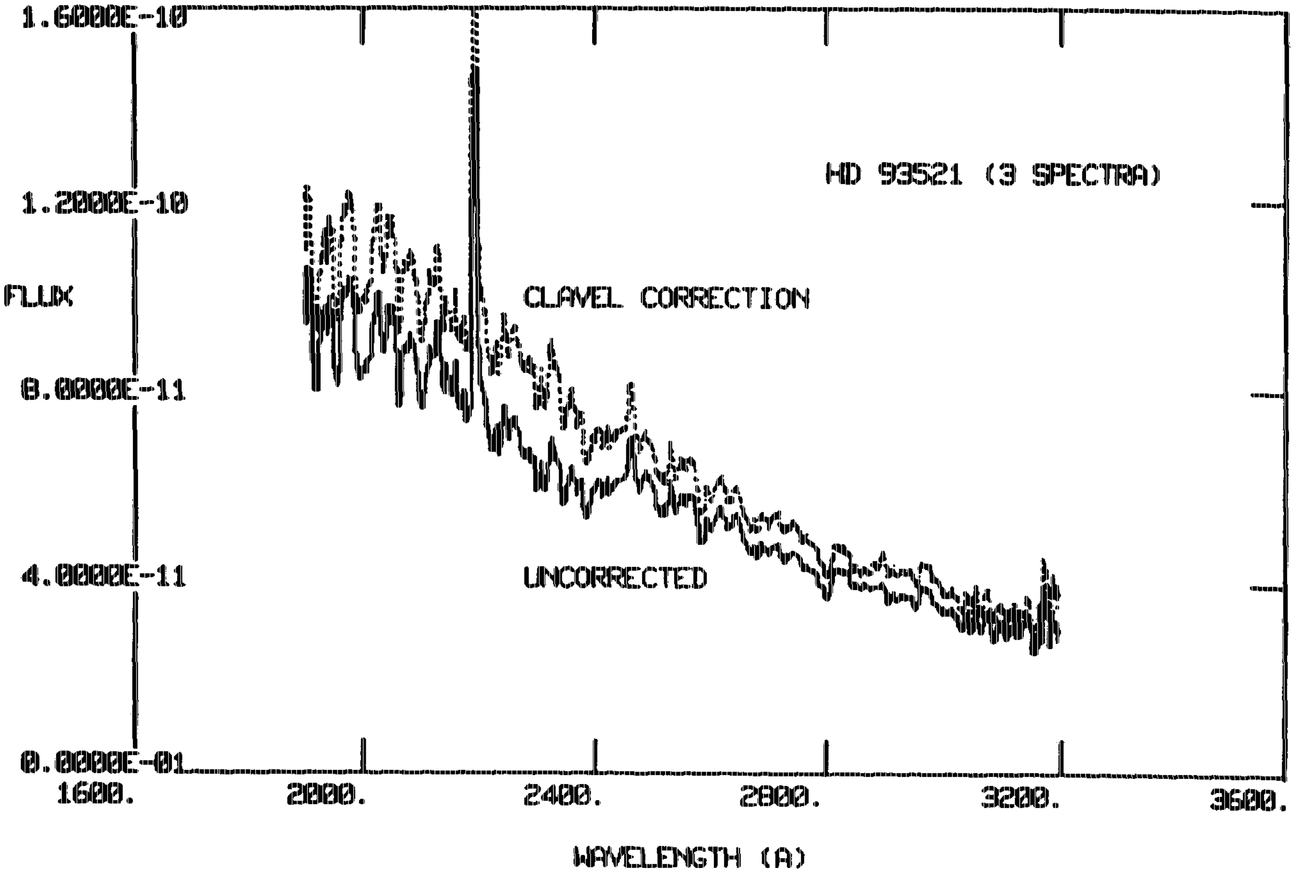

Figure 11. The mean LWR spectrum for HD 93521, uncorrected for degradation (solid line) and corrected using Clavel et al.'s results (dotted line).

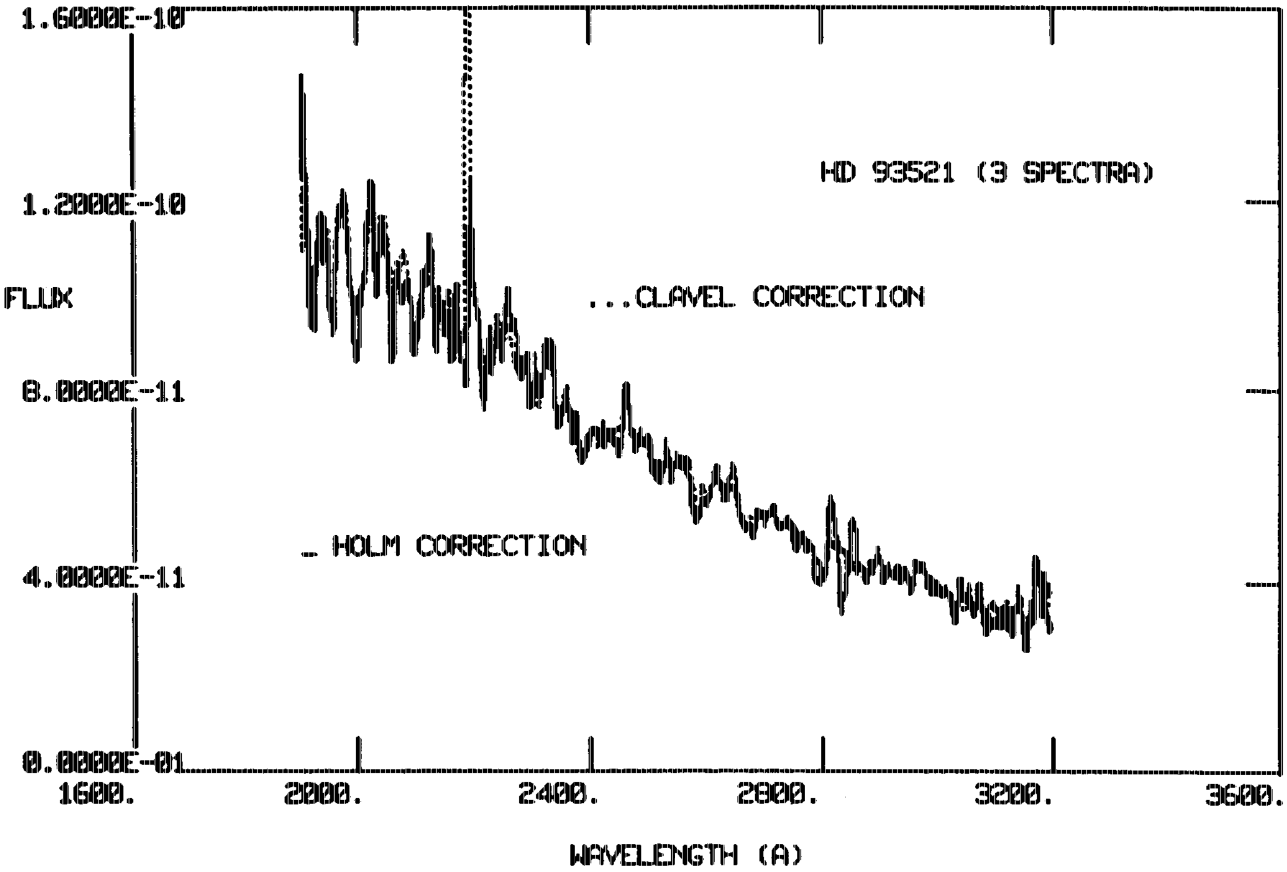

Figure 12. Comparison of the mean LWR spectrum for HD 93521, corrected with Holm's algorithm (solid line) and with Clavel et al.'s method (dotted line).