THE ULTRAVIOLET CALIBRATION OF THE HUBBLE SPACE TELESCOPE:

II. A CORRECTION FOR THE CHANGE IN SENSITIVITY OF THE SWP CAMERA ON IUE

Ralph C. Bohlin and Carl J. Grillmair

Space Telescope Science Institute

To be published in February 1988 issue of the

Astrophysical Journal Supplement Series

Received: 13 April 1987 ; Accepted: 19 August 1987

ABSTRACT

The absolute photometric calibration of the Hubble Space Telescope (HST) in the UV will be based on IUE observations of standard stars. Since the sensitivity of IUE is a function of time, the IUE data must be corrected for the changes that are apparent in the low dispersion spectra of five standard stars. In this paper, a set of 895 spectra is analyzed to find the change in sensitivity of the SWP camera for the first eight years of flight operations. The changes are specified as mean annual spectra with a bin size of 5 Å for each of the three standard, low dispersion modes, where the spectrum for the first year provides a normalization of unity for each wavelength bin. The accuracy of the correction algorithm is about 1% in any 5 Å bin, when applied to a large ensemble of spectra of nominal exposure and low background. For an individual star with only 3-4 spectra, as is typical for the HST standard stars, statistical errors in the 5 Å bins are a few percent; but systematic errors over broader wavelength regions can be corrected to less than about 2%.

The loss in sensitivity is most pronounced at the shortest wavelengths, from 1400 to 1500 Å, and longward of 1800 Å, where the total degradation often exceeds 10%. A set of 30 spectra, obtained after the April 1986 cutoff date for spectra used in deriving the correction, show a mean drop in sensitivity of 8.6% over all wavelengths with a scatter about the mean for the 5 Å bins of 2.7% and with a maximum loss of 20% at 1150 Å. After correcting these data with an extrapolation of the change spectra for the two years previous to April 1986, the mean ratio of the flux relative to the first year is 1.002 with a scatter of 1.7% and a maximum deviation from unity of 5% at wavelengths that are not contaminated by a reseau or the strong Lα line. The correction is generally applicable to all low dispersion IUE spectra from the SWP camera. However, other errors can be larger than the change in sensitivity with time, especially for early data or for a weak response on a high background.

I. INTRODUCTION

Since the IUE Observatory began supporting guest observers in April of 1978, the staff has regularly obtained spectra of the five standard stars HD60753, BD+75°325, HD93521, BD+33°2642, and BD+28°4211 for the purpose of monitoring sensitivity changes. The subset of large aperture, low dispersion spectra were analyzed in broad bandpasses (eg. Sonneborn and Garhart 1986), where the degradations are similar to those expected from radiation damage to the optical coatings. More detailed studies of the LWR degradation, which currently exceeds 20% in the 2300 Å region, have been made by Clavel, Gilmozzi, and Prieto (1986) and by Holm (1985). Both studies assumed that the LWR degraded linearly with time and smoothly with wavelength. Clavel, Gilmozzi, and Prieto found the coefficient of degradation in 50 Å bins, while Holm used a smooth analytic fit as a function of wavelength.

In our analysis of archival data, the sensitivity changes for SWP are found to vary significantly among nearby 5 Å wavelength bins. The rate of change in sensitivity in 5 Å bins is not linear with time. In fact, occasional increases in sensitivity are observed, as shown in Fig. 1 for the 1635 Å bin. Since the neighboring bin at 1640 Å displays the opposite behavior in Fig. 1, bin sizes much greater than 5 Å would not produce the best reduction in scatter from year to year on this fine scale. On the other hand, a bin size much less than the 5-6 Å instrumental resolution below 1800 Å (Cassatella, Barbero, and Benvenuti 1983) would be difficult to justify.

One possible origin of the fine structure changes is the target of the SEC Vidicon camera, which has structure on the one pixel scale. Another possibility is the systematic motion of the spectral format across the camera faceplate (Thompson, Turnrose, and Bohlin 1982). A given wavelength moves on the camera at a mean rate of about 1 pixel per year. Because of noise in the intensity transfer function (ITF) that is used to flat field and linearize the data, the ITF correction will introduce apparent changes in response on the fine scale of a pixel. The SWP low dispersion is 1.67 Å per pixel. Since the changes in time are not monotonic, the calibration data must be examined as a function of time. Fortunately, the changes are small over one year; and enough data are available to establish the mean response level for every 5 Å wavelength bin of every year. The following sections detail the derivation and testing of the annual changes, which are used to find the change at any time by linear interpolation and at any wavelength by using the nearest neighbor bin.

Given a full correction as a function of time and wavelength, the absolute calibration for the initial epoch is applicable for all low dispersion spectra. If a superior absolute calibration is derived for a later epoch, our correction for the change of sensitivity with time will be valid when normalized to unity for the epoch of the new absolute sensitivity determination. The currently recommended absolute calibration of Bohlin (1986) is for the initial epoch and is compared in Bohlin (1986) to the previous initial epoch calibration of Bohlin and Holm (1980), which is the only SWP and LWR calibration ever used by the production data processing.

II. OBSERVATIONS

Table 1 summarizes the number of observations of the five standard stars that are used to monitor the IUE sensitivity in low dispersion. The data are itemized by aperture, since the changes depend on the observing mode: trailed in large aperture (T), small aperture (S), or point source centered in large aperture (L). In order to restrict the analysis to well exposed spectra with little saturation, only spectra with exposure times that differ from the normal time by less than 30% (40% for the small aperture) are used. The original scripts and photowrites were examined to obtain the correct exposure times and to reject images with high background or unusual noise. As an additional check, plots of the average flux from 1150 to 1970 Å were made to identify potential errors in the mean photometric level.

III. ANALYSIS TECHNIQUE

a) General Background

The reduction of each individual spectrum into 5 Å bins followed the procedures of Bohlin (1986). In particular, the early reductions are corrected for wavelength assignments and errors in the ITF for the SWP camera, the correction is made for the dependence of the sensitivity on temperature of $-0.48\%\ C^{-1}$ (Imhoff 1986); and exposure times are reduced by the 0.12 s high voltage rise time. The clock digitization of 0.4096 s and the large aperture length of 21.4 arcsec are used, as appropriate. However, flux values affected by a reseau are estimated by linear interpolation between unaffected data from either side of the reseau. Since the small aperture spectra are not photometric, only changes in the shape of the sensitivity with wavelength are relevant. All small aperture spectra are normalized by dividing by the mean level of the 5 Å bins from 1600-1725 Å.

For each observing mode (T, S, or L) different portions of the photocathode are illuminated, so that each mode is best thought of as an independent spectrograph. Because of the fine structure in the IUE sensitivity, each 5 Å wavelength bin must also be treated independently. However, these complications are moderated by the fact that the IUE sensitivity changes slowly with time, so that the data can be averaged over time periods of a year. Thus, spectra for each star and for each aperture separately can be binned in time periods of one year, starting at 1978.36, the beginning of observatory operations.

Starting with a set of average annual fluxes F(i,t), the goal of the analysis is to find the relative response f(t) for each of the eight years, t, from 1978.36 to 1986.36. The index, i, has a value from 1 to 5 and denotes one of the standard stars. Since the analysis is the same for each 5 Å wavelength bin and for each of the three aperture modes, the subscripting over wavelength and aperture is implicit. The relative response f(0) for the first year is unity to correspond to the epoch of the absolute sensitivity found by Bohlin (1986). The F(i,t) for any individual star can be normalized to unity for the first year and will provide a measure of relative change in sensitivity with time. The problem is to merge all of the information from the 5 stars using proper weights to get a best estimate of f(t).

b) Detailed Procedure

Our procedure for combining the F(i,t) for each independent observing mode and 5 Å wavelength bin follows (compare Bevington 1969):

1. Choose the best-observed star as the starting point, F(1,t) and rank the remaining 4 stars through F(5,t).

2. Compute for each star, i, and each time bin, t, the number of spectra averaged N(i,t) and the error in the mean σ(i,t) for F(i,t), where

$$\sigma^2(i,t) = \sigma^2_{rms}(i,t)/N(i,t). \tag{1}$$

   The root mean square scatter among the individual spectra determines σ_{rms} in the same units as F. To avoid artificially small values of σ for values of N from 2 to 5, use a floor value of

$$\sigma^2(i,t) = (C\,F(i,t))^2/N(i,t), \tag{2}$$

   where the mean fractional scatter, C, from Bohlin (1986) is 0.047 for SWP (and 0.067 for LWR) point source spectra. Use C = 0.024 (or 0.034) for trailed spectra, since a trailed spectrum has almost 4 times the signal of a point source spectrum.

3. Since the mean fluxes and the errors in the mean are uncorrelated from one star to another, compute the ratio R(2,t) = F(1,t)/F(2,t) for each annual time bin and the fractional error in the mean for each ratio,

$$\sigma^2_R(t) = \left[\frac{\sigma(1,t)}{F(1,t)}\right]^2 + \left[\frac{\sigma(2,t)}{F(2,t)}\right]^2 \tag{3}$$

Bins with $N(i,t) = 0$ or 1 spectrum are not used.

4. Compute the mean ratio $R(2)$ to normalize all time bins of star 2 to those of star 1:

$$R(2) = \frac{\Sigma\, w_R(t)\, R(2,t)}{\Sigma\, w_R(t)}, \tag{4}$$

where the sum is over the 8 time bins and the weights are

$$w_R(t) = 1/\sigma_R^2(t). \tag{5}$$

5. Compute an updated best spectrum $F(1+2,t)$ and error estimate $\sigma(1+2,t)$ by combining the first and second stars:

$$F(1+2,t) = \frac{w(1,t)\; F(1,t) + w(2,t)\; R(2)\; F(2,t)}{w(1,t) + w(2,t)}, \tag{6}$$

where $w(i,t) = 1/[R(i)\sigma(i,t)]^2$ and $R(1) = 1$ and

$$\sigma^2(1+2,t) = \frac{1}{w(1,t) + w(2,t)}. \tag{7}$$

6. Find the values of $R(i)$ for the remaining stars by using the updated starting values of F and σ from step 5 and iterating steps 3 to 5.

7. After completion of the derivation of the values of $R(i)$ in phase I, phase II begins with the multiplication of the mean flux $F(i,t)$ by $R(i)$ to bring all the stars to the same scale. Average the results for all stars to find the mean relative response:

$$f(t) = \frac{\Sigma\, w(i,t)\; R(i)\; F(i,t)}{\Sigma\, w(i,t)}, \tag{8}$$

where the probable error in the mean is

$$\sigma^2(t) = \frac{1}{\Sigma w(i,t)} \tag{9}$$

and the rms scatter about the mean for the n stars is

$$\sigma_{rms}^2(t) = \left[\frac{\Sigma\, w(i,t)\; (R(i)\; F(i,t))^2}{\Sigma\, w(i,t)} - f^2(t)\right] \frac{n}{n-1}. \tag{10}$$

The sums are over $i=1$ to n stars, where $n=5$ for the L and S modes and $n=4$ for the T mode, since trailed exposure times are too long for BD+33°2642. Remember that the procedure is repeated for each independent wavelength and each of the 3 independent observing modes. Consequently, $f(t)$ represents the complete family of solutions, where the wavelength and aperture mode subscripts are implicit.

8. The set of $f(t)$ can be normalized to unity for the epoch of any particular absolute calibration. For the absolute calibration of Bohlin (1986) for the initial year of IUE, the results are normalized to unity for the first year by dividing all $f(t)$ values by $f(1)$. This result will be referred to as the normalized correction $f(t)$ and appears as Table 2. Only the errors in the mean, $\sigma(t)$ after conversion to a percent error, appear in Table 2, because the two errors given by Equations 9 and 10 differ only by the square root of n, on the average, and because the rms scatter among 4 or 5

stars is statistically erratic for individual points. The mean time for each annual time bin in Table 2 is the weighted average over all spectra in each year beginning at 1978.36.

c) Special Considerations

In order to get a complete solution, linear interpolation of the data on either side of a reseau is used to estimate the flux in the region of the reseau. Occasionally, the stellar flux is not smooth enough for accurate interpolation. In these case, the wavelengths are masked out of the solution. Other masks are necessary for wavelengths in regions of prominent spectral features. The small IUE wavelength errors of 1-2 Å make the photometry unreliable, if a large spectral gradient in the flux exists within a 5 Å bin. The masked bins and the reasons for their exclusion are listed in Table 3. The Lα line is an especially problematic region. At 1210, 1215, and 1220 Å, only *BD+75°325 is* useful in defining the change of sensitivity, making this weak-lined star *the most essential standard* source for monitoring the IUE sensitivity.

d) Verifications of the Method

Equation 10, the rms scatter among the results for the 5 stars, is a good indication of the expected error of the correction in a 5 Å bin for an average of many spectra of a single star, while the error in the mean is indicative of the expected uncertainty in an ensemble of well observed stars. The value of $\sigma_{rms}(t)$ has an average over all the 165 wavelengths and eight time bins of 1.3%, 1.4%, and 1.2% for the trailed, small, and large apertures, respectively. The largest average $\sigma_{rms}(t)$ over time is 7.1% for the small aperture at 1150 Å, where the signal is low.

One check on the validity of the results is to continue the iterations of steps 3-5 above, using the data for the first star as a sixth star. If the technique is valid, the mean ratio R(6) should be near unity. The worst deviations from unity are 0.9, 2.8, and 0.7% all at 1150 Å for the trail, small, and large aperture data sets, respectively.

Another simple verification is to use a different star to start the iterations. The SWP large aperture solution differs by a maximum of 0.2%, when starting with HD60753 instead of BD+75°325.

A final verification is provided by a more elegant mathematical technique that requires no special selection of one star as a starting point for the solution. Instead, Eq. 11 is solved simultaneously for the r(i) and f(t) which minimize the reduced χ^2 for:

$$\chi^2 = 1/28\ \Sigma[F(i,t) - r(i)\ f(t)]^2/\sigma^2(i,t). \qquad (11)$$

The sum is over the 5 stars (i=1,5) and the 8 annual time bins (t=1,8), and the number of degrees of freedom is 5 x 8 - 5 - 8 + 1 = 28. To solve this non-linear equation, the MINUIT minimization program from CERN is used. The solution for two sample wavelengths 1150 and 1970 Å for the large aperture differ from the results shown in Table 2 by less than 0.4% at 1150 Å and by less than 0.1% at 1970 Å. The estimated errors also agree within 20%.

IV. APPLICATION OF THE CORRECTIONS

a) Recipe

Given an arbitrary SWP low dispersion spectrum $A(\lambda,T)$ the spectrum corrected for the change in sensitivity is

$$A'(\lambda,T) = A(\lambda,T)/f(\lambda',T), \qquad (12)$$

where λ' is the closest 5 Å bin and $f(\lambda',T)$ is the linear interpolation of $f(t)$ in time for the proper observing mode from Table 2. Linear interpolation or extrapolation past 1986.36 from the two time bins nearest to T is appropriate because of the smooth changes from year to year, as shown for selected wavelengths in Fig. 1. Since the changes with wavelength are not smooth, the choice of the nearest neighbor at wavelength λ' is more appropriate than interpolation in wavelength. A test using SWP 2900 confirmed that the nearest neighbor is preferable. The mean fluxes for SWP 2900 were found in 5 Å bins and used as corrections to the original unbinned fluxes by linear interpolation and by the nearest neighbor technique. A perfect algorithm would produce a unit result in all rebinned 5 Å intervals. The mean deviation of all bins from unity is 1.1% for linear interpolation, while the nearest neighbor is significantly better with only a 0.7% average error. A Fortran 77 subroutine to read in and apply the correction is included as Appendix A.

b) Test Results

A series of tests compare the fluxes for the first year of IUE operations beginning in 1978 to the fluxes in the later years, before and after correction. The 1978 data, which were taken during the period 1978.36 to 1979.36, for the five standard stars are an expansion on the set of spectra used to define the fluxes of these fundamental UV standards published in Paper I of this series (Bohlin 1986). All trailed and point source spectra from both apertures are corrected according to Eq. 12 and averaged together to get the new 1978 baseline fluxes, which have a higher statistical weight than the baseline from paper I. The mean ratio of this more complete 1978 baseline to the Paper I fluxes is within 1% of unity for all five stars, when averaged over all wavelengths. However, this ensemble average does have fluxes that are systematically about 1% higher than the Paper I fluxes longward of 1550 Å. This 1% shift in the mean fluxes is a confirmation of the Bohlin (1986) calibration, since 1% is small in comparison to the 10% error of the absolute calibration. In making comparisons of relative change, 1% is important; and therefore, the more comprehensive 1978 baseline is recommended over the Paper I fluxes for the highest precision. These SWP revised baseline fluxes will be published along with the revised LWR fluxes in Paper III of this series.

To illustrate the net degradation in a recent epoch with high statistical weight, all the 1985 spectra for each of the five standard stars are averaged and divided by the respective 1978 baseline. The mean of all five of these ratios, both before and after correcting the 1985 data for the loss of sensitivity, is shown in Fig. 2. The mean of the ratios over the region 1230-1970 Å of 1.000 and the corresponding scatter of the 5 Å bins about the mean of 0.8% are indicative of the limiting accuracy of the correction method for a large sample of spectra. The total number of spectra involved in this analysis is 142 in 1978 and 86 in 1985.

As a more demanding test of the correction technique, similar results for a set of spectra taken after 1986.36 are shown in Fig. 3. These 1986 data provide a completely independent check, since they are not used to determine the correction values, in contrast to the 1985 data discussed above. In addition, the correction of the 1986 spectra requires an extrapolation from the 1984 and 1985 corrections. Only two stars with a total of 30 spectra are considered in Fig. 3, but the corrections are excellent with a mean ratio of 0.914 before and a mean ratio of 1.002 and rms scatter of 1.7% after correction. The conclusion based on Fig. 1 that changes in sensitivity are smooth and gradual on one year timescales is substantiated.

Historically, an alternative correction technique was envisaged to make sensitivity corrections to the HST standard star data obtained on 16 shifts awarded in 1983 and 1984. Comprehensive observations were made of four of the five standards in order to determine sensitivity changes at those two points in time. Since then, new observations of HST standards have been obtained at GSFC and at Vilspa specifically for HST calibration and incidentally by other observers. To obtain single point corrections in time for uncoordinated observations is not possible. Thus, our simple strategy had to change to one of a global correction technique, good for all low dispersion spectra in the archive. The special observations obtained of four of the five IUE standards as part of our earlier IUE program for HST calibration are used with the general sample to define the correction and also serve to validate the general purpose correction at the times when the bulk of the HST standards were observed.

As a check that is especially relevant for HST calibration, the set of spectra that were obtained in 1983 and 1984 for four of the five IUE standards are corrected and compared to the 1978 baseline fluxes. These spectra were observed using the same technique as the set of HST standard stars. The HST standard spectra included heavy overexposure to bring up the signal in regions of low sensitivity. Since the overexposures are typically a factor of two longer than the optimum and are outside the limits of ±30% imposed in Table 1 for the large aperture, the linearity of SWP data is also being tested. Over the region 1230-1970 Å, the average of the four ratios is corrected to within 1.001 of the baseline fluxes with a corresponding rms scatter of the mean ratio in the 5 Å bins of 1.1%. Even though the average result is excellent, the mean ratio for one star, BD+75°325, is anomolous at a mean of 1.018 and rms scatter of 1.5%. Part of the 1.8% systematic error may be attributed to non-linearities, but BD+28°4211 with a comparable degree of over-exposure has a corrected mean ratio of 0.994 with a 1.7% scatter.

The correction is valid for individual spectra but has been verified for large ensembles of spectra, because the photometric repeatability of a single IUE spectrum is comparable to the size of the time correction in many cases. For the 5 Å bands, the one sigma scatter is 5% (Bohlin 1986), while broader bands repeat to a one sigma of about 3% (Bohlin et al. 1980). Nevertheless, a variety of individual spectra are examined. The worst performance of the linear interpolation of the annual corrections should be at the beginning and end of the first year of operations, since the change in sensitivity is the greatest between the first and second years. From 1350 to 1500 Å and from 1750 to 1900 Å, the loss in sensitivity is about 4-5% in the first year, which is comparable to the additional loss in years 2-8. The 1485 Å point in Fig. 1 is typical of these wavelength regions. For the period 1978.36-1978.46 at the beginning, 11 spectra are studied, while 14 individual spectra are analyzed for 1979.30-1979.50 at the end of the first year. These totals represent all of the spectra from the five standard stars and for all three aperture modes in these time intervals. All of these spectra were corrected using the mean annual change spectra for 1978.9 and 1979.9, binned in 5 Å intervals, and ratioed to the mean spectrum for the first year. All ratios of individual spectra are within the expected photometric accuracy of unity. Over the 1230-1970 Å region, the mean of the ratios for 6 L and T spectra from 1978.36-1978.46 improves from 1.012 before correction to 1.000 after correction, while the corresponding improvement for the 9 L and T spectra from 1979.30-1979.50 is from 0.985 to 0.997.

The correction technique should be valid for individual spectra with long exposure times. In order to check the validity directly, pairs of spectra of the same non-variable source with an observation date separated by several years and with exposure times longer than one hour were sought in the IUE archive. Unfortunately, no suitable pairs were found after imposing the added necessary constraints of a smooth continuum and low background. Spectra with strong lines tend to have noisy ratios, while high backgrounds cause non-linearity errors on the order of 5% (Oliversen 1984).

V. DISCUSSION

The sensitivity in the low dispersion mode of the SWP camera is changing slowly with time but has significant wavelength dependent structure on the 5 Å scale. An independent correction is required for each observing mode (trailed, small aperture, and point source in the large aperture) to bring all spectra to the sensitivity scale of the first year. The broadband shapes of the sensitivity loss differ by small but significant amounts among the three modes. For example longward of 1800 Å, trailed spectra show about a 3% larger sensitivity loss than large aperture point sources. The fine structure is typically ~3% for point sources and ~2% for trailed spectra and shows little correlation among modes. This fine structure is real, because the probable errors from Equation 9 are less than 1% and because the same fine structure pattern for the same aperture mode is recognizable in the change spectra of each of the five individual stars.

The correction is derived from well exposed spectra with low background and has been verified for an independent set of similar spectra. The technique is recommended but is difficult to directly validate for weak exposures or for images with high backgrounds. For multiple exposures in the large aperture, the trail corrections are probably the most appropriate. If the broadband trends are a result of degradation of the optics, then the general shape of any spectrum should be properly corrected. If the changes that scatter about a smooth mean by less than 5% (typically 2-3%) on the 5 Å scale are in the camera, then our results should be generally applicable to any low dispersion spectrum. If the fine structure is caused by noise in the ITF, then the fine structure in the correction may not be appropriate for poor exposures. A test of whether the fine structure is a physical change in the SWP camera or just noise in the ITF could be done by fitting smooth curves as a function of wavelength to the change spectra of Table 2. Then, a test set of weak exposures could be corrected both ways, with the smooth corrections and with the original Table 2 functions. If the ratio of the spectra corrected using Table 2 to the baseline spectra is smoother, then there are probably changes in the camera that are similar for all exposure levels. Conversely, if the smooth corrections produce smoother ratios, then the noise in the ITF is probably to blame. However, such a test is probably not worth the effort, because the relevant case of a scientifically interesting object with 10-20 weak spectra on a low background is unlikely to exist, even if the archives contain enough weak spectra of the five standard stars to do a statistically significant test. Weak spectra on a high background is an even less relevant case, since the intrinsic noise in these spectra is large in comparison with the 2-3% scatter in the fine structure of the correction. A similar experiment could be done for overexposed spectra, but saturation and extrapolation of the ITF add complexity to the above considerations for weak exposures. Therefore, the corrections of Table 2 are recommended for all SWP spectra.

After the mode dependent correction for the sensitivity change is made, the first year calibrations (Bohlin 1986) can be used to bring the fluxes for each mode to the same absolute scale. The errors in these absolute fluxes will no longer be dominated by the change in sensitivity.

If the IUE archive is ever reprocessed with a different ITF, the corrections of Table 2 may still be applicable, but should be verified or derived again from reprocessed spectra.

Helpful discussions on various aspects of this work were provided by C. Blades, J. Bohlin, K. Horne, C. Imhoff, G. Sonneborn, D. Turnshek, W. Wamsteker, and R. White. In particular, R. White supplied insight into the mysterious details of statistical analysis and produced the results quoted from the MINUIT software. In general, we thank the IUE staff at the Goddard Space Flight Center, who obtained much of the data and are always happy to discuss any technical detail.

REFERENCES

Bevington, P. R. 1969, Data Reduction and Error Analysis for the Physical Sciences, (New York: McGraw-Hill).

Bohlin, R. C. 1986, Ap. J., 308, 1001.

Bohlin, R. C., Holm, A. V., Savage, B. D., Snijders, M. A. J., and Sparks, W. M. 1980, Astron. Astrophys., 85, 1.

Cassatella, A., Barbero, J., and Benvenuti, P. 1983, IUE ESA Newsletter, 18, 38; and 1984, IUE NASA Newsletter, 24, 84.

Clavel, J., Gilmozzi, R., and Prieto, A. 1987, Astron. Astrophys., in press.

Holm, A. V. 1985, IUE NASA Newsletter, 26, 11.

Imhoff, C. 1986, IUE NASA Newsletter, 31, 11.

Oliversen, N. A. 1984, IUE NASA Newsletter, 24, 27.

Sonneborn, G., and Garhart, M. P. 1986, IUE NASA Newsletter, 31, 29.

Thompson, R. W., Turnrose, B. E., and Bohlin, R. C. 1982, Astron. Astrophys., 107, 11.

TABLE 1
OBSERVATIONS OF PROGRAM STARS BETWEEN APRIL 1978 AND APRIL 1986

	Exposure Time (s)[a]			No. of Spectra		
Star	T[b]	S[b]	L[b]	T[b]	S[b]	L[b]
HD60753	41 (29-54)	20 (12-30)	10 (7-13)	62	68	110
BD+75°325	52 (39-72)	28 (17-42)	14 (10-18)	36	64	128
HD93521	12 (8-15)	6 (4-9)	3 (2.1-4)	23	57	93
BD+33°2642	---	480 (288-720)	240 (168-312)	--	17	77
BD+28°4211	96 (67-125)	52 (31-73)	26 (18-34)	33	30	97

[a] Nominal commanded exposure time in seconds, with the acceptable range in parentheses.

[b] T - Trailed spectrum in large aperture. S - Source in small aperture. L - Point source centered in large aperture.

TABLE 2a

SENSITIVITY CHANGES - TRAILED SPECTRA

	t=1978.90		t=1979.88		t=1980.76		t=1981.73		t=1982.92		t=1983.95		t=1984.88		t=1985.75	
λ (Å)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)
1150	1.000	3.0	1.098	1.0	1.032	1.0	0.951	1.5	0.889	0.9	0.819	0.9	0.759	1.1	0.761	1.1
1155	1.000	2.2	1.036	1.5	0.975	1.2	0.913	0.9	0.855	0.8	0.789	0.7	0.774	1.1	0.770	1.5
1160	1.000	2.5	1.024	1.0	0.979	1.0	0.961	0.9	0.920	0.6	0.852	0.6	0.841	0.7	0.836	1.5
1165	1.000	1.4	1.041	1.2	1.012	1.0	0.975	0.8	0.931	0.6	0.880	0.7	0.858	0.7	0.860	0.8
1170	1.000	1.5	0.967	1.2	0.983	0.8	0.964	0.6	0.908	0.6	0.871	0.6	0.842	0.7	0.815	1.6
1175	1.000	2.0	0.973	0.9	0.942	1.2	0.925	0.6	0.879	0.7	0.828	0.6	0.812	0.7	0.824	1.2
1180	1.000	2.3	1.024	0.8	1.022	0.8	0.993	0.6	0.935	0.6	0.880	0.6	0.876	0.7	0.883	1.5
1185	1.000	4.5	0.974	1.1	0.999	0.9	0.943	0.7	0.900	0.8	0.870	0.6	0.851	0.9	0.836	2.8
1190	1.000	3.7	0.938	1.0	0.990	0.9	0.961	0.8	0.904	0.8	0.888	0.7	0.870	0.8	0.865	1.4
1195	1.000	3.8	0.947	1.1	0.997	0.7	1.009	0.8	0.951	0.8	0.928	0.6	0.913	0.8	0.903	1.7
1200	1.000	3.9	0.999	1.0	0.976	1.1	0.995	0.5	0.949	0.9	0.912	0.4	0.909	0.7	0.904	1.5
1205	1.000	3.0	0.987	1.1	0.993	0.8	0.994	0.7	0.948	0.9	0.930	0.5	0.914	0.9	0.920	1.2
1210	1.000	4.3	0.975	1.9	0.982	5.0	1.016	2.3	0.984	2.5	0.977	1.7	0.943	2.0	0.000	0.0
1215	1.000	3.4	1.079	3.4	1.210	6.9	0.985	2.1	0.905	1.3	0.872	1.0	0.862	4.2	0.000	0.0
1220	1.000	5.0	1.058	1.4	1.095	2.4	1.038	1.3	0.965	1.1	0.926	1.3	0.929	2.7	0.000	0.0
1225	1.000	2.9	1.018	1.0	1.024	0.8	1.026	0.8	0.986	0.8	0.970	0.5	0.959	0.7	0.963	1.7
1230	1.000	1.5	1.005	1.0	1.000	0.8	1.013	0.8	0.979	0.6	0.956	0.4	0.947	0.6	0.989	0.8
1235	1.000	1.4	0.987	1.1	0.997	0.8	1.028	0.8	0.983	0.6	0.974	0.4	0.957	0.7	0.978	0.8
1240	1.000	1.9	1.014	1.2	1.020	1.0	1.011	0.6	0.977	0.6	0.950	0.4	0.952	0.6	0.947	0.8
1245	1.000	1.2	0.980	1.1	0.994	0.8	1.013	0.6	0.963	0.5	0.941	0.3	0.931	0.6	0.927	1.0
1250	1.000	1.1	0.988	1.0	1.005	0.7	1.028	0.5	0.986	0.5	0.970	0.4	0.967	0.5	0.981	0.7
1255	1.000	1.0	0.991	1.0	1.010	0.7	1.017	0.6	0.983	0.5	0.961	0.3	0.965	0.6	0.941	1.0
1260	1.000	0.8	0.968	0.9	0.977	0.7	0.999	0.6	0.958	0.5	0.945	0.4	0.936	0.6	0.929	1.0
1265	1.000	1.3	0.985	0.9	1.009	0.7	1.023	0.7	0.985	0.5	0.968	0.5	0.970	0.6	0.992	0.9
1270	1.000	1.1	1.005	1.0	1.019	0.7	1.032	0.6	0.989	0.5	0.972	0.4	0.983	0.6	0.975	0.9
1275	1.000	0.9	0.965	1.1	0.986	0.8	0.999	0.7	0.965	0.4	0.951	0.4	0.948	0.5	0.938	0.8
1280	1.000	1.0	0.974	0.9	0.987	0.8	1.008	0.6	0.975	0.6	0.959	0.5	0.955	0.6	0.957	0.8
1285	1.000	1.2	0.980	1.0	0.994	0.9	1.009	0.6	0.964	0.4	0.951	0.4	0.946	0.4	0.935	0.9
1290	1.000	1.0	0.978	0.8	0.998	0.9	1.027	0.7	0.981	0.4	0.971	0.3	0.961	0.5	0.951	0.8
1295	1.000	1.1	0.955	0.9	0.976	0.8	1.003	0.7	0.950	0.5	0.959	0.4	0.943	0.7	0.909	1.0
1300	1.000	1.0	0.941	1.1	0.951	0.9	0.979	0.6	0.946	0.5	0.935	0.4	0.932	0.6	0.917	0.8
1305	1.000	1.2	1.001	0.8	1.013	0.9	1.023	0.7	0.986	0.5	0.970	0.5	0.974	0.6	0.984	1.0
1310	1.000	1.4	0.991	0.8	1.004	0.8	1.027	0.8	0.995	0.5	0.969	0.4	0.977	0.6	1.010	0.7
1315	1.000	1.7	0.987	0.9	1.008	0.7	1.037	0.8	0.991	0.8	0.986	0.5	0.992	0.7	0.992	1.6
1320	1.000	2.2	0.975	0.8	1.009	0.7	1.043	0.8	1.002	0.8	0.990	0.6	0.991	0.7	0.999	1.7
1325	1.000	2.2	0.986	0.8	1.024	0.7	1.042	0.8	0.990	0.8	0.986	0.6	0.972	0.8	0.993	1.4
1330	1.000	1.2	0.962	1.1	0.996	0.7	1.027	0.9	0.987	0.5	0.992	0.5	0.973	0.6	0.957	1.0
1335	1.000	1.2	0.936	0.9	0.950	0.8	0.968	0.5	0.926	0.5	0.912	0.4	0.910	0.5	0.933	0.8
1340	1.000	1.7	0.982	0.9	1.003	0.8	1.010	0.6	0.985	0.5	0.959	0.4	0.967	0.5	0.958	0.9
1345	1.000	1.1	0.982	1.1	1.002	0.7	1.008	0.5	0.968	0.5	0.954	0.4	0.952	0.5	0.946	0.8
1350	1.000	0.9	0.964	0.9	0.997	0.7	1.010	0.6	0.967	0.5	0.947	0.4	0.943	0.5	0.940	0.9
1355	1.000	1.0	0.955	0.8	0.979	0.8	0.990	0.6	0.954	0.5	0.944	0.4	0.940	0.5	0.939	0.7
1360	1.000	0.9	0.954	0.9	0.966	0.7	0.979	0.6	0.941	0.4	0.930	0.4	0.927	0.6	0.911	0.9
1365	1.000	1.1	0.951	0.8	0.968	0.7	0.980	0.6	0.941	0.4	0.924	0.3	0.925	0.6	0.920	0.9
1370	1.000	1.1	0.963	0.9	0.975	0.7	1.007	0.6	0.977	0.4	0.963	0.4	0.964	0.5	0.954	0.8
1375	1.000	1.1	0.966	0.9	0.984	0.7	0.984	0.6	0.938	0.4	0.925	0.4	0.924	0.5	0.913	0.8
1380	1.000	1.3	0.953	0.8	0.960	0.8	0.970	0.6	0.939	0.4	0.923	0.4	0.924	0.5	0.912	0.9
1385	1.000	1.0	0.952	0.9	0.968	0.7	0.984	0.7	0.950	0.5	0.947	0.4	0.939	0.5	0.925	0.6
1390	1.000	1.0	0.930	0.9	0.967	0.7	0.991	0.8	0.952	0.5	0.949	0.4	0.933	0.6	0.896	0.8
1395	1.000	0.8	0.947	0.9	0.972	0.8	0.981	0.4	0.937	0.4	0.922	0.4	0.925	0.5	0.932	0.7
1400	1.000	1.0	0.945	0.9	0.953	0.8	0.974	0.6	0.948	0.4	0.944	0.5	0.930	0.5	0.907	0.8
1405	1.000	1.1	0.956	1.1	0.977	0.9	0.972	0.7	0.955	0.4	0.930	0.5	0.929	0.6	0.914	0.8
1410	1.000	1.0	0.958	1.0	0.977	0.8	0.984	0.5	0.940	0.5	0.923	0.3	0.922	0.5	0.913	0.7
1415	1.000	0.8	0.921	1.0	0.943	0.8	0.952	0.7	0.924	0.4	0.915	0.4	0.904	0.5	0.887	0.7
1420	1.000	1.0	0.951	0.9	0.974	0.7	0.970	0.6	0.932	0.3	0.924	0.3	0.923	0.5	0.916	0.8

TABLE 2a - *Continued*

SENSITIVITY CHANGES - TRAILED SPECTRA

λ (Å)	t=1978.90		t=1979.88		t=1980.76		t=1981.73		t=1982.92		t=1983.95		t=1984.88		t=1985.75	
	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)
1425	1.000	1.1	0.933	1.0	0.958	0.7	0.955	0.6	0.929	0.4	0.921	0.5	0.913	0.6	0.905	0.7
1430	1.000	0.9	0.950	0.9	0.971	0.7	0.956	0.6	0.922	0.4	0.897	0.3	0.897	0.5	0.880	0.8
1435	1.000	1.1	0.950	0.9	0.958	0.8	0.972	0.6	0.953	0.5	0.945	0.4	0.942	0.5	0.926	0.7
1440	1.000	0.9	0.947	0.9	0.953	0.7	0.961	0.5	0.927	0.4	0.917	0.3	0.912	0.5	0.900	0.8
1445	1.000	0.8	0.939	0.9	0.964	0.9	0.957	0.6	0.932	0.4	0.915	0.2	0.921	0.6	0.906	0.7
1450	1.000	1.1	0.934	0.9	0.950	0.7	0.958	0.6	0.934	0.4	0.930	0.4	0.929	0.5	0.918	0.7
1455	1.000	1.3	0.944	0.9	0.946	0.7	0.949	0.6	0.922	0.5	0.910	0.4	0.906	0.5	0.904	0.7
1460	1.000	0.9	0.952	0.9	0.960	0.7	0.956	0.5	0.933	0.4	0.922	0.4	0.927	0.5	0.910	0.8
1465	1.000	0.9	0.952	1.0	0.958	0.7	0.955	0.4	0.927	0.5	0.914	0.4	0.910	0.6	0.904	0.7
1470	1.000	0.8	0.964	0.8	0.971	0.7	0.966	0.4	0.947	0.5	0.925	0.5	0.937	0.5	0.917	0.7
1475	1.000	0.7	0.943	1.0	0.960	0.7	0.955	0.5	0.931	0.5	0.921	0.4	0.921	0.5	0.911	0.8
1480	1.000	0.7	0.967	0.8	0.968	0.7	0.961	0.5	0.931	0.5	0.918	0.4	0.918	0.5	0.906	0.8
1485	1.000	1.0	0.959	0.9	0.965	0.7	0.949	0.4	0.929	0.4	0.909	0.3	0.908	0.5	0.906	0.7
1490	1.000	1.0	0.953	0.8	0.967	0.7	0.972	0.5	0.945	0.4	0.926	0.4	0.930	0.6	0.911	0.8
1495	1.000	0.9	0.929	0.8	0.950	0.8	0.950	0.5	0.926	0.5	0.913	0.4	0.914	0.5	0.897	0.6
1500	1.000	1.1	0.936	1.1	0.950	0.7	0.962	0.5	0.940	0.5	0.938	0.4	0.933	0.4	0.914	0.6
1505	1.000	1.3	0.937	1.0	0.952	0.7	0.934	0.5	0.925	0.5	0.916	0.4	0.917	0.6	0.905	1.0
1510	1.000	1.0	0.922	0.9	0.930	0.7	0.929	0.6	0.918	0.5	0.893	0.4	0.893	0.5	0.877	0.7
1515	1.000	0.7	0.928	1.1	0.939	0.7	0.934	0.4	0.906	0.5	0.897	0.4	0.905	0.5	0.887	0.7
1520	1.000	0.8	0.941	1.0	0.944	0.8	0.948	0.5	0.925	0.3	0.907	0.4	0.910	0.5	0.894	0.6
1525	1.000	0.8	0.929	0.9	0.939	0.7	0.940	0.6	0.912	0.5	0.907	0.4	0.903	0.5	0.883	0.7
1530	1.000	1.0	0.949	1.0	0.981	0.7	0.966	0.5	0.948	0.4	0.939	0.4	0.940	0.5	0.924	0.8
1535	1.000	1.0	0.949	0.9	0.969	0.7	0.962	0.4	0.933	0.4	0.929	0.3	0.931	0.4	0.924	0.7
1540	1.000	1.0	0.939	0.9	0.951	0.8	0.969	0.6	0.939	0.4	0.939	0.4	0.937	0.4	0.927	0.7
1545	1.000	1.0	0.952	0.9	0.969	0.9	0.972	0.6	0.946	0.4	0.943	0.3	0.942	0.6	0.908	0.7
1550	1.000	1.0	0.972	1.2	0.977	0.8	0.979	0.5	0.949	0.6	0.934	0.5	0.944	0.5	0.932	0.8
1555	1.000	1.0	0.977	1.0	0.994	0.8	0.988	0.5	0.950	0.5	0.943	0.4	0.943	0.5	0.933	0.9
1560	1.000	1.1	0.925	0.9	0.958	0.8	0.958	0.6	0.940	0.4	0.932	0.4	0.933	0.5	0.924	0.6
1565	1.000	1.1	0.951	0.8	0.987	0.7	0.985	0.5	0.955	0.5	0.955	0.4	0.961	0.5	0.961	0.8
1570	1.000	1.1	0.980	0.8	0.996	0.7	0.988	0.5	0.957	0.5	0.946	0.4	0.948	0.5	0.943	0.8
1575	1.000	1.1	0.971	0.9	0.991	0.7	0.979	0.5	0.956	0.5	0.941	0.4	0.947	0.6	0.944	0.7
1580	1.000	1.0	0.958	0.9	0.966	0.7	0.974	0.3	0.949	0.4	0.936	0.4	0.941	0.4	0.932	0.7
1585	1.000	1.3	0.983	0.9	0.981	0.7	0.980	0.6	0.957	0.4	0.939	0.5	0.956	0.5	0.947	0.6
1590	1.000	1.1	0.958	0.8	0.974	0.7	0.972	0.5	0.950	0.4	0.941	0.3	0.945	0.6	0.924	0.6
1595	1.000	0.8	0.952	0.8	0.965	0.7	0.967	0.5	0.945	0.5	0.944	0.5	0.936	0.5	0.930	0.8
1600	1.000	0.7	0.952	0.8	0.962	0.7	0.971	0.5	0.947	0.4	0.945	0.3	0.935	0.5	0.925	0.6
1605	1.000	0.9	0.945	0.8	0.960	0.8	0.963	0.5	0.941	0.5	0.934	0.4	0.920	0.5	0.914	0.7
1610	1.000	0.9	0.951	0.9	0.960	0.7	0.970	0.6	0.942	0.4	0.940	0.3	0.941	0.4	0.923	0.7
1615	1.000	1.2	0.966	0.9	0.987	0.7	0.995	0.5	0.956	0.4	0.948	0.5	0.956	0.6	0.951	0.8
1620	1.000	1.3	0.967	0.9	0.975	0.8	0.977	0.6	0.944	0.4	0.935	0.4	0.944	0.5	0.943	0.8
1625	1.000	1.1	0.955	0.8	0.996	0.7	0.983	0.5	0.959	0.5	0.942	0.4	0.948	0.5	0.950	0.7
1630	1.000	0.8	0.946	0.9	0.968	0.7	0.957	0.6	0.939	0.4	0.928	0.4	0.934	0.6	0.928	0.7
1635	1.000	1.0	0.924	0.8	0.941	0.9	0.969	0.7	0.942	0.4	0.949	0.5	0.946	0.5	0.932	0.9
1640	1.000	0.9	0.968	1.0	0.983	0.9	0.972	0.5	0.944	0.4	0.942	0.4	0.943	0.5	0.933	0.7
1645	1.000	1.1	0.982	0.9	1.002	0.8	0.982	0.4	0.951	0.4	0.934	0.5	0.936	0.5	0.935	0.8
1650	1.000	0.9	0.940	0.8	0.965	0.7	0.971	0.6	0.938	0.4	0.944	0.4	0.935	0.5	0.932	0.8
1655	1.000	0.9	0.932	0.8	0.949	0.7	0.958	0.5	0.918	0.4	0.919	0.5	0.914	0.5	0.905	0.8
1660	1.000	0.9	0.936	0.8	0.954	0.8	0.972	0.5	0.940	0.3	0.938	0.4	0.929	0.4	0.917	0.8
1665	1.000	0.9	0.948	0.8	0.963	0.8	0.978	0.6	0.959	0.4	0.957	0.4	0.957	0.4	0.957	1.0
1670	1.000	0.8	0.937	0.9	0.957	0.7	0.958	0.7	0.944	0.5	0.940	0.4	0.936	0.5	0.922	0.6
1675	1.000	0.9	0.969	0.8	0.985	0.7	0.983	0.4	0.949	0.4	0.940	0.3	0.943	0.3	0.934	0.8
1680	1.000	1.1	0.951	0.9	0.961	0.7	0.964	0.4	0.942	0.3	0.939	0.5	0.936	0.6	0.920	0.7
1685	1.000	1.1	0.945	0.8	0.969	0.8	0.971	0.5	0.946	0.3	0.935	0.3	0.936	0.5	0.930	0.7
1690	1.000	1.0	0.947	0.8	0.967	0.8	0.957	0.6	0.935	0.4	0.927	0.3	0.931	0.5	0.918	0.7
1695	1.000	0.6	0.967	0.8	0.975	0.8	0.965	0.5	0.932	0.5	0.930	0.4	0.930	0.4	0.919	0.7

TABLE 2a - *Continued*

SENSITIVITY CHANGES - TRAILED SPECTRA

	t=1978.90		t=1979.88		t=1980.76		t=1981.73		t=1982.92		t=1983.95		t=1984.88		t=1985.75	
λ (Å)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)
1700	1.000	0.8	0.957	0.9	0.968	0.7	0.963	0.5	0.936	0.4	0.932	0.3	0.927	0.3	0.920	0.6
1705	1.000	1.0	0.940	0.9	0.950	0.7	0.964	0.5	0.935	0.4	0.935	0.4	0.935	0.5	0.914	0.7
1710	1.000	1.0	0.936	0.9	0.949	0.8	0.959	0.5	0.936	0.4	0.925	0.3	0.930	0.5	0.915	0.8
1715	1.000	1.0	0.936	0.8	0.939	0.8	0.954	0.7	0.936	0.5	0.925	0.4	0.920	0.5	0.915	0.7
1720	1.000	0.9	0.938	0.9	0.960	0.8	0.955	0.6	0.931	0.4	0.913	0.5	0.906	0.5	0.901	0.7
1725	1.000	1.5	0.966	0.8	0.962	0.7	0.958	0.6	0.941	0.5	0.911	0.4	0.923	0.6	0.920	0.6
1730	1.000	1.4	0.968	0.9	0.985	0.7	0.954	0.4	0.930	0.3	0.912	0.3	0.918	0.5	0.909	0.8
1735	1.000	1.1	0.937	0.9	0.959	0.7	0.965	0.4	0.937	0.4	0.914	0.4	0.922	0.5	0.907	0.6
1740	1.000	0.9	0.944	0.9	0.957	0.7	0.960	0.4	0.931	0.4	0.918	0.4	0.917	0.5	0.909	0.7
1745	1.000	0.8	0.957	0.8	0.959	0.7	0.958	0.5	0.924	0.4	0.913	0.3	0.904	0.5	0.897	0.7
1750	1.000	1.0	0.943	1.0	0.956	0.8	0.960	0.4	0.932	0.4	0.924	0.3	0.919	0.5	0.914	0.8
1755	1.000	0.8	0.929	0.9	0.943	0.7	0.943	0.5	0.922	0.4	0.908	0.3	0.912	0.4	0.896	0.8
1760	1.000	0.9	0.934	0.8	0.947	0.7	0.942	0.6	0.922	0.3	0.909	0.2	0.908	0.5	0.898	0.8
1765	1.000	0.9	0.964	0.9	0.970	0.7	0.960	0.5	0.932	0.4	0.915	0.3	0.921	0.4	0.903	0.7
1770	1.000	1.0	0.946	0.9	0.957	0.7	0.953	0.5	0.934	0.2	0.919	0.4	0.922	0.4	0.896	0.8
1775	1.000	1.0	0.953	0.8	0.960	0.7	0.954	0.5	0.930	0.4	0.919	0.4	0.922	0.6	0.905	0.6
1780	1.000	1.0	0.944	0.8	0.955	0.7	0.951	0.6	0.927	0.4	0.911	0.4	0.912	0.4	0.902	0.7
1785	1.000	1.0	0.943	0.8	0.945	0.7	0.944	0.5	0.928	0.4	0.911	0.4	0.915	0.5	0.900	0.7
1790	1.000	1.0	0.953	0.8	0.950	0.7	0.945	0.5	0.917	0.3	0.907	0.4	0.901	0.4	0.895	0.7
1795	1.000	1.0	0.960	0.8	0.952	0.7	0.947	0.4	0.916	0.3	0.905	0.4	0.902	0.4	0.895	0.7
1800	1.000	1.0	0.943	0.8	0.951	0.7	0.947	0.6	0.918	0.3	0.908	0.4	0.902	0.4	0.898	0.6
1805	1.000	0.9	0.940	0.8	0.928	0.8	0.926	0.5	0.895	0.3	0.892	0.4	0.886	0.4	0.873	0.8
1810	1.000	0.9	0.931	0.9	0.924	0.7	0.917	0.5	0.896	0.4	0.887	0.3	0.887	0.4	0.871	0.8
1815	1.000	0.9	0.941	0.8	0.941	0.7	0.930	0.4	0.907	0.3	0.889	0.4	0.890	0.5	0.871	0.7
1820	1.000	0.8	0.942	0.8	0.939	0.7	0.940	0.4	0.912	0.3	0.896	0.4	0.893	0.4	0.879	0.8
1825	1.000	0.9	0.948	1.0	0.954	0.7	0.948	0.5	0.921	0.4	0.911	0.2	0.907	0.4	0.898	0.7
1830	1.000	0.9	0.948	1.0	0.957	0.7	0.949	0.5	0.917	0.3	0.911	0.4	0.911	0.5	0.895	0.8
1835	1.000	1.0	0.934	0.8	0.943	0.7	0.946	0.6	0.926	0.3	0.921	0.5	0.922	0.5	0.900	0.7
1840	1.000	1.0	0.922	0.9	0.929	0.7	0.918	0.5	0.900	0.4	0.895	0.4	0.888	0.5	0.871	0.7
1845	1.000	0.9	0.929	0.8	0.939	0.7	0.927	0.5	0.907	0.5	0.895	0.4	0.891	0.4	0.876	0.7
1850	1.000	0.9	0.912	0.8	0.929	0.7	0.922	0.6	0.899	0.4	0.900	0.3	0.893	0.5	0.878	0.8
1855	1.000	0.9	0.925	0.8	0.938	0.7	0.923	0.5	0.892	0.4	0.887	0.4	0.879	0.5	0.863	0.6
1860	1.000	1.0	0.947	0.8	0.947	0.7	0.955	0.4	0.917	0.4	0.910	0.4	0.901	0.4	0.885	0.5
1865	1.000	0.9	0.951	0.8	0.946	0.7	0.950	0.4	0.918	0.4	0.908	0.3	0.907	0.4	0.896	0.6
1870	1.000	1.1	0.938	0.8	0.934	0.7	0.930	0.4	0.905	0.4	0.892	0.4	0.892	0.5	0.882	0.6
1875	1.000	0.9	0.942	0.9	0.930	0.7	0.930	0.5	0.908	0.4	0.892	0.3	0.890	0.5	0.877	0.7
1880	1.000	0.9	0.919	0.9	0.923	0.7	0.919	0.6	0.894	0.4	0.885	0.4	0.879	0.6	0.864	0.6
1885	1.000	0.8	0.919	0.9	0.921	0.7	0.916	0.6	0.901	0.4	0.893	0.4	0.889	0.5	0.871	0.6
1890	1.000	0.9	0.922	0.9	0.926	0.7	0.927	0.5	0.903	0.4	0.888	0.3	0.888	0.5	0.864	0.5
1895	1.000	0.8	0.932	0.9	0.942	0.7	0.924	0.5	0.897	0.4	0.882	0.3	0.889	0.5	0.876	0.7
1900	1.000	0.7	0.935	0.9	0.935	0.8	0.934	0.4	0.911	0.4	0.895	0.3	0.897	0.5	0.883	0.7
1905	1.000	0.9	0.929	0.9	0.928	0.8	0.933	0.4	0.905	0.4	0.887	0.3	0.891	0.5	0.876	0.6
1910	1.000	0.8	0.929	0.8	0.934	0.7	0.919	0.4	0.903	0.4	0.888	0.3	0.885	0.5	0.872	0.6
1915	1.000	0.8	0.934	0.8	0.917	0.8	0.918	0.5	0.898	0.4	0.886	0.1	0.875	0.4	0.866	0.7
1920	1.000	0.9	0.935	0.8	0.914	0.7	0.910	0.4	0.884	0.4	0.865	0.4	0.864	0.4	0.845	0.7
1925	1.000	0.9	0.934	0.8	0.911	0.7	0.900	0.3	0.872	0.4	0.853	0.5	0.853	0.5	0.832	0.7
1930	1.000	0.9	0.931	0.8	0.921	0.7	0.910	0.3	0.874	0.5	0.847	0.5	0.853	0.5	0.837	0.5
1935	1.000	1.0	0.957	0.8	0.950	0.7	0.946	0.5	0.923	0.3	0.904	0.4	0.902	0.4	0.884	0.5
1940	1.000	0.9	0.949	0.8	0.948	0.7	0.933	0.3	0.904	0.3	0.888	0.4	0.880	0.3	0.869	0.6
1945	1.000	1.0	0.955	0.9	0.951	0.7	0.933	0.4	0.910	0.4	0.893	0.4	0.890	0.4	0.881	0.7
1950	1.000	0.9	0.948	1.0	0.944	0.7	0.927	0.3	0.901	0.4	0.887	0.3	0.880	0.5	0.871	0.7
1955	1.000	0.7	0.938	0.8	0.930	0.7	0.917	0.4	0.893	0.4	0.877	0.3	0.873	0.3	0.862	0.6
1960	1.000	0.8	0.964	0.9	0.942	0.7	0.930	0.3	0.911	0.4	0.903	0.4	0.894	0.4	0.881	0.7
1965	1.000	0.9	0.978	1.0	0.947	0.7	0.924	0.3	0.898	0.4	0.890	0.3	0.882	0.4	0.874	0.5
1970	1.000	0.9	1.015	1.1	0.967	0.8	0.936	0.4	0.909	0.3	0.894	0.4	0.890	0.4	0.876	0.6

TABLE 2b

SENSITIVITY CHANGES - SMALL APERTURE

	t=1978.89		t=1979.84		t=1980.85		t=1981.81		t=1982.83		t=1983.98		t=1984.95		t=1985.82	
λ (Å)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)
1150	1.000	2.5	1.124	1.7	1.054	2.1	1.121	2.5	0.938	1.8	0.844	1.2	0.839	1.9	0.846	2.4
1155	1.000	1.3	1.045	1.3	1.019	1.6	1.041	1.4	0.941	1.5	0.850	1.3	0.837	1.6	0.824	1.8
1160	1.000	1.3	1.006	1.4	0.996	1.9	1.028	1.7	0.948	1.4	0.887	1.1	0.904	1.6	0.856	2.0
1165	1.000	1.1	1.020	0.7	1.047	1.1	1.041	0.9	1.001	1.3	0.929	1.2	0.930	1.3	0.899	1.6
1170	1.000	0.9	0.979	0.8	0.946	1.4	0.968	0.9	0.963	1.0	0.910	1.1	0.890	1.5	0.879	1.8
1175	1.000	1.0	1.024	0.8	1.001	1.4	0.980	1.3	0.908	0.9	0.909	0.9	0.900	1.5	0.877	1.5
1180	1.000	1.0	1.049	0.8	1.046	0.9	1.033	1.2	0.978	1.2	0.933	0.9	0.926	1.1	0.911	1.5
1185	1.000	0.8	1.022	0.6	1.008	0.8	1.024	0.9	0.970	0.9	0.934	0.8	0.921	1.2	0.901	2.0
1190	1.000	0.8	1.019	0.6	0.994	0.7	0.981	0.6	0.959	0.9	0.919	0.7	0.912	1.3	0.906	1.6
1195	1.000	0.7	1.048	0.7	1.048	0.7	1.046	0.7	1.025	1.0	0.973	0.9	0.995	1.2	0.982	1.5
1200	1.000	0.8	1.032	0.7	1.016	0.8	0.990	0.9	0.980	1.5	0.972	0.7	0.932	1.5	0.898	1.6
1205	1.000	0.8	1.005	0.7	1.033	1.1	1.019	1.0	1.019	1.8	0.977	1.1	0.970	1.6	0.947	1.8
1210	1.000	1.2	1.019	1.5	0.998	1.9	0.937	5.9	1.003	2.7	1.015	1.8	0.973	2.1	0.918	2.7
1215	1.000	1.6	1.051	1.1	1.040	2.3	1.155	7.3	0.992	3.9	1.014	2.3	0.973	2.1	0.945	2.7
1220	1.000	2.6	1.048	1.6	1.099	3.2	1.109	4.7	1.035	2.7	0.959	3.1	0.980	2.1	1.109	2.7
1225	1.000	0.7	1.031	0.6	1.031	1.1	1.043	1.1	1.029	1.8	0.984	1.1	0.995	1.6	0.971	1.7
1230	1.000	0.6	1.045	0.6	1.036	0.9	1.018	0.7	1.007	1.1	1.004	0.7	0.980	1.0	0.989	1.4
1235	1.000	0.6	1.030	0.8	1.029	0.8	1.043	1.3	1.036	1.1	1.030	0.9	0.999	1.1	0.975	1.5
1240	1.000	0.9	1.000	0.6	1.038	1.1	1.061	1.1	1.033	1.1	1.015	1.0	1.017	1.2	0.956	1.6
1245	1.000	0.5	1.020	0.5	1.034	1.0	1.032	0.8	1.037	0.8	1.019	0.9	1.007	1.0	0.987	1.4
1250	1.000	0.5	1.019	0.6	1.036	0.8	1.049	0.7	1.029	0.9	1.020	0.8	0.992	1.2	0.988	1.4
1255	1.000	0.6	1.018	0.5	1.059	1.0	1.053	0.7	1.067	1.0	1.056	0.7	1.041	0.9	1.016	1.4
1260	1.000	0.4	1.009	0.5	1.052	1.0	1.042	0.8	1.021	1.0	1.024	0.6	1.023	1.0	0.987	1.4
1265	1.000	0.5	1.019	0.5	1.054	0.9	1.055	0.8	1.044	1.0	1.053	0.8	1.051	1.0	1.031	1.4
1270	1.000	0.5	1.029	0.5	1.053	0.9	1.050	0.9	1.045	0.8	1.037	0.7	1.032	0.7	0.991	1.5
1275	1.000	0.5	1.046	0.5	1.080	0.8	1.076	0.6	1.071	1.4	1.073	0.7	1.053	1.3	1.011	1.5
1280	1.000	0.5	1.004	0.5	1.014	0.9	1.040	0.6	1.015	1.4	1.026	1.0	1.018	0.9	0.983	1.6
1285	1.000	0.5	1.014	0.6	1.023	0.9	1.031	0.8	1.042	1.4	1.022	1.1	1.036	1.0	1.008	1.7
1290	1.000	0.5	1.023	0.5	1.065	1.0	1.051	1.0	1.081	1.3	1.067	1.1	1.063	0.6	1.048	1.7
1295	1.000	0.6	0.967	0.5	1.030	1.2	1.031	1.3	1.060	1.1	1.069	1.0	1.070	0.9	1.019	1.6
1300	1.000	0.5	1.014	0.7	1.052	0.8	1.038	0.6	1.047	1.2	1.050	0.5	1.053	0.8	1.004	1.4
1305	1.000	0.7	1.029	0.6	1.037	1.0	1.055	0.9	0.998	1.4	0.993	0.7	1.006	1.0	0.984	1.4
1310	1.000	0.6	1.032	0.6	1.069	0.9	1.055	0.9	1.056	1.1	1.034	0.8	1.029	1.3	0.995	1.5
1315	1.000	0.6	1.030	0.6	1.037	0.8	1.026	0.8	1.017	1.3	1.045	0.9	1.035	1.0	1.003	1.7
1320	1.000	0.6	1.004	0.5	1.014	1.0	1.036	0.8	1.023	1.4	1.009	0.9	1.019	1.0	0.971	1.7
1325	1.000	0.5	1.005	0.6	1.036	1.0	1.019	0.4	1.017	1.3	1.015	1.0	1.013	0.7	1.000	1.6
1330	1.000	0.6	0.989	0.6	1.014	0.9	1.016	0.9	1.057	0.9	1.046	0.9	1.022	1.1	0.996	1.7
1335	1.000	0.5	0.994	0.6	1.013	0.8	1.023	0.6	0.979	1.2	0.992	1.1	0.974	0.8	0.975	1.6
1340	1.000	0.7	1.014	0.5	1.028	0.7	1.021	0.7	1.022	1.5	1.028	0.6	1.032	1.2	0.982	1.5
1345	1.000	0.5	1.024	0.3	1.027	0.7	1.035	0.8	1.042	1.0	1.026	0.8	1.015	0.6	0.989	1.6
1350	1.000	0.5	1.025	0.6	1.038	0.9	1.034	0.7	1.030	0.8	1.012	1.0	1.027	0.9	0.991	1.4
1355	1.000	0.5	1.000	0.7	1.027	0.5	1.033	0.7	1.030	0.7	1.022	1.0	1.014	0.4	0.980	1.5
1360	1.000	0.5	1.010	0.6	1.034	0.7	1.036	0.6	1.040	1.3	1.040	0.8	1.030	0.6	0.985	1.5
1365	1.000	0.5	1.019	0.7	1.027	0.8	1.029	0.9	1.022	1.0	1.011	0.6	1.016	0.8	1.001	1.4
1370	1.000	0.6	1.008	0.7	1.034	0.7	1.047	0.9	1.031	1.0	1.034	0.7	1.009	1.0	0.985	1.5
1375	1.000	0.4	1.012	0.6	1.033	0.9	1.043	0.6	1.063	0.5	1.009	1.0	1.011	1.3	0.985	1.5
1380	1.000	0.5	0.984	0.5	1.019	0.8	1.022	0.8	1.033	0.9	1.018	0.5	1.013	1.0	1.020	1.4
1385	1.000	0.4	0.972	0.6	0.986	0.5	0.992	0.7	1.004	1.0	1.003	0.6	0.994	0.9	0.966	1.4
1390	1.000	0.5	0.982	0.5	0.963	0.9	0.974	0.9	1.010	1.0	1.016	0.8	0.986	1.0	0.944	1.6
1395	1.000	0.7	1.006	0.7	0.996	0.8	0.988	0.9	1.006	1.0	0.971	0.6	0.979	0.9	0.976	1.7
1400	1.000	0.8	0.995	0.6	0.998	0.5	1.002	0.9	1.031	0.8	1.021	0.5	0.979	1.0	0.953	1.5
1405	1.000	0.7	1.006	0.6	1.015	0.7	0.998	0.8	1.006	0.3	0.965	0.8	0.984	0.9	0.959	1.5
1410	1.000	0.5	1.006	0.4	0.998	0.8	0.996	0.7	0.994	0.9	1.001	0.6	1.004	1.1	1.007	1.4
1415	1.000	0.5	0.973	0.4	0.991	0.4	0.990	0.6	1.011	0.8	1.003	0.5	1.001	1.0	0.974	1.5
1420	1.000	0.6	0.985	0.5	0.991	0.7	0.980	0.6	0.991	1.0	0.967	0.6	0.975	0.4	0.962	1.4

TABLE 2b - *Continued*

SENSITIVITY CHANGES - SMALL APERTURE

λ (Å)	t=1978.89		t=1979.84		t=1980.85		t=1981.81		t=1982.83		t=1983.98		t=1984.95		t=1985.82	
	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)
1425	1.000	0.6	0.982	0.5	0.997	0.7	0.994	0.5	0.980	0.9	0.980	0.5	0.983	0.8	0.962	1.5
1430	1.000	0.5	1.005	0.5	1.012	0.8	1.002	0.5	0.996	0.7	0.987	0.6	0.994	0.8	0.964	1.4
1435	1.000	0.6	1.007	0.4	1.012	0.8	1.011	0.6	0.972	0.8	0.977	0.4	0.960	0.8	0.946	1.4
1440	1.000	0.7	0.988	0.5	1.008	0.7	1.011	0.6	1.000	0.8	0.991	0.5	0.981	0.9	0.955	1.4
1445	1.000	0.5	0.982	0.5	0.996	0.6	0.982	0.5	0.977	0.8	0.977	0.5	0.970	1.0	0.968	1.4
1450	1.000	0.5	0.989	0.5	0.992	0.6	1.005	0.5	1.017	0.6	1.016	0.5	1.008	1.0	0.983	1.5
1455	1.000	0.6	0.989	0.5	0.962	0.8	0.965	0.5	0.973	0.7	0.944	0.6	0.944	1.0	0.937	1.4
1460	1.000	0.5	0.986	0.5	0.970	0.6	0.968	0.4	0.977	0.4	0.940	0.9	0.944	1.0	0.918	1.5
1465	1.000	0.6	0.978	0.6	0.982	0.5	0.968	0.7	0.961	1.0	0.942	0.8	0.939	1.0	0.940	1.4
1470	1.000	0.5	0.995	0.7	1.002	0.5	1.013	0.6	1.028	0.8	1.012	0.5	1.010	1.0	0.999	1.4
1475	1.000	0.4	0.988	0.4	0.994	0.7	0.983	0.6	0.979	0.8	0.978	0.4	0.973	0.8	0.962	1.5
1480	1.000	0.7	0.982	0.5	0.984	0.7	0.976	0.5	0.957	0.8	0.964	0.5	0.963	0.8	0.931	1.4
1485	1.000	0.6	0.999	0.6	0.993	0.6	0.991	0.6	0.985	0.8	0.991	0.4	0.978	0.8	0.966	1.4
1490	1.000	0.4	0.965	0.4	0.961	0.7	0.983	0.5	0.990	1.1	0.990	0.6	0.992	1.1	0.989	1.5
1495	1.000	0.5	0.970	0.4	0.953	0.6	0.956	0.4	0.961	0.7	0.953	0.6	0.937	0.8	0.913	1.6
1500	1.000	0.5	0.997	0.6	0.981	0.6	0.979	0.6	0.992	0.9	0.993	0.8	0.960	1.3	0.969	1.6
1505	1.000	0.5	0.989	0.5	0.983	0.5	0.963	0.7	0.973	0.7	0.971	0.8	0.980	1.0	0.965	1.4
1510	1.000	0.6	0.989	0.5	1.006	0.3	0.999	0.8	0.992	0.7	0.998	0.6	0.985	0.8	0.967	1.4
1515	1.000	0.5	0.990	0.6	0.979	0.5	0.981	0.6	0.976	0.9	0.972	0.6	0.962	0.9	0.950	1.5
1520	1.000	0.5	0.995	0.5	1.002	0.5	0.969	0.6	0.959	0.8	0.966	0.7	0.948	0.9	0.961	1.5
1525	1.000	0.8	0.976	0.7	0.972	0.8	0.968	0.8	0.967	1.1	0.983	0.6	0.963	0.9	0.947	1.4
1530	1.000	0.6	0.973	0.6	0.970	0.6	0.980	0.4	0.978	0.7	0.967	0.5	0.958	0.9	0.954	1.5
1535	1.000	0.6	0.979	0.5	0.998	0.6	0.983	0.6	0.974	0.5	0.949	0.7	0.964	0.9	0.958	1.4
1540	1.000	0.7	0.987	0.7	0.995	0.8	1.008	0.7	1.029	1.0	1.045	0.6	1.029	0.9	1.030	1.5
1545	1.000	0.8	0.964	0.6	0.978	1.1	0.974	0.9	1.019	1.3	1.008	0.9	0.995	1.3	0.999	1.7
1550	1.000	1.0	0.987	0.6	0.979	0.8	0.990	0.5	0.972	0.4	0.985	0.8	0.990	1.0	0.987	1.6
1555	1.000	0.7	1.002	0.7	0.984	0.7	0.966	0.8	0.927	0.9	0.922	0.5	0.904	0.7	0.928	1.6
1560	1.000	0.7	1.005	0.6	1.001	0.6	0.991	0.9	1.008	0.9	0.995	0.8	0.977	0.5	0.962	1.7
1565	1.000	0.6	1.030	0.6	1.011	0.7	0.999	0.6	0.996	0.9	0.985	0.7	0.995	1.0	0.989	1.4
1570	1.000	0.6	1.011	0.3	1.009	0.8	1.008	0.6	1.021	0.5	0.994	0.5	1.002	1.0	0.985	1.7
1575	1.000	0.6	1.026	0.6	1.002	0.6	0.999	0.4	1.008	0.9	1.003	0.5	0.996	0.6	0.995	1.4
1580	1.000	0.4	1.003	0.4	1.005	0.6	1.000	0.7	1.016	1.1	1.004	0.7	1.007	0.9	1.027	1.4
1585	1.000	0.5	0.988	0.6	0.961	0.6	0.954	0.5	0.973	1.0	0.996	0.7	1.006	1.0	1.015	1.4
1590	1.000	0.5	0.995	0.6	0.972	0.6	0.966	0.5	0.973	0.9	0.993	0.7	1.002	0.9	1.005	1.4
1595	1.000	0.7	1.017	0.5	1.025	0.7	0.997	0.6	0.976	0.7	0.996	0.7	0.997	0.8	1.009	1.4
1600	1.000	0.6	0.983	0.6	0.987	0.5	1.003	0.6	1.005	0.8	1.014	0.6	1.005	0.9	0.994	1.4
1605	1.000	0.5	1.017	0.5	1.014	0.5	1.018	0.6	1.022	0.9	1.013	0.7	1.009	0.9	1.022	1.4
1610	1.000	0.6	1.016	0.4	1.020	0.7	1.008	0.5	0.990	0.8	1.007	0.6	1.011	0.9	1.017	1.5
1615	1.000	0.4	1.006	0.5	1.008	0.5	1.027	0.5	1.024	0.9	1.021	0.6	1.027	1.0	1.031	1.5
1620	1.000	0.5	1.006	0.6	1.017	0.6	1.012	0.6	1.025	0.6	1.019	0.6	1.029	1.0	1.027	1.5
1625	1.000	0.5	1.018	0.5	1.027	0.5	1.033	0.5	1.011	0.7	1.036	0.7	1.028	1.0	1.022	1.4
1630	1.000	0.6	1.002	0.6	0.989	0.6	0.995	0.5	0.990	1.0	0.990	0.6	0.996	0.8	0.987	1.4
1635	1.000	0.5	1.001	0.5	1.003	0.7	0.999	0.7	1.015	0.6	1.012	0.4	1.023	0.5	1.032	1.5
1640	1.000	0.6	1.003	0.5	0.990	0.5	0.989	0.6	0.994	1.0	0.991	0.7	0.994	1.0	0.989	1.5
1645	1.000	0.5	1.018	0.4	1.021	0.5	1.013	0.5	1.029	0.6	1.017	0.5	1.011	0.8	1.000	1.5
1650	1.000	0.5	0.992	0.5	0.980	0.6	0.988	0.6	0.997	0.8	1.010	0.6	1.001	0.8	1.011	1.6
1655	1.000	0.5	0.985	0.5	1.010	0.6	1.014	0.6	1.005	0.8	1.007	0.5	1.004	0.8	1.007	1.5
1660	1.000	0.4	1.003	0.4	1.007	0.5	1.016	0.7	1.010	0.8	1.005	0.5	1.022	0.6	1.027	1.4
1665	1.000	0.4	0.988	0.4	1.001	0.5	1.014	0.7	1.024	0.6	1.030	0.5	1.026	0.8	1.054	1.4
1670	1.000	0.5	0.965	0.4	0.972	0.6	0.978	0.4	0.972	0.7	0.992	0.7	0.978	0.8	0.982	1.4
1675	1.000	0.5	0.987	0.5	1.001	0.5	0.999	0.8	0.998	1.0	0.974	0.5	0.980	0.8	0.997	1.4
1680	1.000	0.5	1.009	0.4	1.006	0.5	0.993	0.7	1.004	0.8	0.987	0.5	1.010	0.8	1.013	1.4
1685	1.000	0.4	0.993	0.4	0.991	0.5	0.988	0.4	0.981	0.7	0.992	0.6	0.996	0.7	0.991	1.5
1690	1.000	0.6	0.991	0.5	0.971	0.5	0.958	0.5	0.959	0.8	0.957	0.4	0.952	0.9	0.927	1.4
1695	1.000	0.4	0.998	0.4	0.990	0.7	0.979	0.4	0.977	0.6	0.968	0.6	0.949	0.9	0.952	1.4

TABLE 2b - *Continued*

SENSITIVITY CHANGES - SMALL APERTURE

λ (Å)	t=1978.89		t=1979.84		t=1980.85		t=1981.81		t=1982.83		t=1983.98		t=1984.95		t=1985.82	
	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)
1700	1.000	0.5	1.004	0.4	1.002	0.3	0.987	0.4	0.990	0.5	0.987	0.5	0.979	0.6	0.976	1.6
1705	1.000	0.5	0.996	0.4	1.006	0.5	1.020	0.7	1.015	0.7	1.013	0.4	0.999	0.5	1.001	1.4
1710	1.000	0.5	1.008	0.6	1.021	0.6	1.016	0.4	1.017	0.5	1.014	0.5	1.020	0.5	1.004	1.4
1715	1.000	0.5	0.999	0.5	0.985	0.7	0.987	1.0	0.998	0.5	1.011	0.5	0.986	0.9	0.971	1.4
1720	1.000	0.5	1.006	0.8	0.983	1.0	0.977	0.6	0.984	0.8	0.979	0.5	0.996	0.6	0.977	1.4
1725	1.000	0.6	0.994	0.4	1.000	0.6	0.990	0.7	0.977	1.0	0.965	0.6	0.986	0.6	0.963	1.4
1730	1.000	0.5	0.986	0.3	0.968	0.6	0.961	0.5	0.965	0.9	0.943	0.5	0.944	0.8	0.934	1.4
1735	1.000	0.5	1.004	0.4	0.986	0.5	0.975	0.4	0.962	0.8	0.946	0.5	0.943	0.8	0.949	1.4
1740	1.000	0.4	1.000	0.4	0.969	0.5	0.973	0.5	0.968	0.6	0.956	0.3	0.953	0.8	0.941	1.5
1745	1.000	0.5	0.998	0.5	0.964	0.6	0.964	0.5	0.963	0.7	0.938	0.4	0.930	0.9	0.932	1.4
1750	1.000	0.5	0.979	0.4	0.968	0.5	0.973	0.5	0.951	0.7	0.946	0.4	0.906	0.9	0.926	1.4
1755	1.000	0.5	0.989	0.5	0.971	0.6	0.978	0.4	0.969	0.7	0.965	0.6	0.952	0.6	0.958	1.4
1760	1.000	0.4	0.978	0.5	0.968	0.5	0.956	0.4	0.949	0.8	0.950	0.5	0.930	0.8	0.908	1.4
1765	1.000	0.5	0.984	0.4	0.985	0.5	0.969	0.5	0.964	1.0	0.943	0.5	0.932	0.8	0.926	1.4
1770	1.000	0.5	0.978	0.5	0.977	0.5	0.976	0.4	0.970	0.8	0.958	0.3	0.949	0.7	0.937	1.4
1775	1.000	0.5	0.976	0.4	0.961	0.5	0.969	0.4	0.955	0.8	0.962	0.5	0.927	1.1	0.928	1.4
1780	1.000	0.5	0.983	0.5	0.959	0.5	0.965	0.4	0.951	0.8	0.954	0.5	0.932	0.9	0.924	1.4
1785	1.000	0.5	0.983	0.4	0.960	0.5	0.955	0.4	0.949	0.7	0.948	0.4	0.937	1.0	0.928	1.4
1790	1.000	0.4	0.982	0.4	0.970	0.5	0.964	0.4	0.946	0.6	0.956	0.5	0.936	0.9	0.935	1.5
1795	1.000	0.5	0.981	0.4	0.961	0.7	0.948	0.5	0.930	1.2	0.930	0.5	0.914	0.8	0.929	1.5
1800	1.000	0.5	0.979	0.4	0.954	0.6	0.961	0.3	0.947	0.8	0.946	0.4	0.930	1.0	0.917	1.4
1805	1.000	0.5	0.961	0.4	0.941	0.5	0.943	0.6	0.927	0.9	0.933	0.4	0.915	0.7	0.908	1.5
1810	1.000	0.5	0.981	0.4	0.956	0.5	0.937	0.5	0.934	0.8	0.935	0.4	0.917	0.7	0.905	1.4
1815	1.000	0.5	1.004	0.5	0.975	0.4	0.964	0.4	0.965	0.8	0.960	0.4	0.942	0.6	0.939	1.5
1820	1.000	0.5	0.985	0.5	0.965	0.5	0.957	0.4	0.956	1.2	0.948	0.4	0.926	0.9	0.928	1.4
1825	1.000	0.5	0.987	0.5	0.966	0.6	0.963	0.4	0.959	1.2	0.954	0.5	0.936	0.7	0.952	1.4
1830	1.000	0.5	0.988	0.5	0.962	0.5	0.960	0.5	0.961	1.2	0.959	0.4	0.955	0.8	0.953	1.4
1835	1.000	0.5	0.973	0.6	0.950	0.6	0.954	0.7	0.961	0.5	0.972	0.5	0.955	0.9	0.960	1.4
1840	1.000	0.6	0.970	0.5	0.954	0.8	0.956	0.6	0.956	0.9	0.970	0.6	0.955	0.7	0.942	1.4
1845	1.000	0.5	0.961	0.6	0.935	0.6	0.937	0.6	0.928	1.0	0.920	0.6	0.899	1.0	0.885	1.5
1850	1.000	0.6	0.959	0.7	0.947	0.5	0.948	0.7	0.946	1.1	0.938	0.5	0.904	0.8	0.909	1.4
1855	1.000	0.6	0.966	0.6	0.968	0.5	0.953	0.5	0.952	0.8	0.952	0.6	0.932	0.8	0.940	1.4
1860	1.000	0.6	0.973	0.5	0.966	0.8	0.954	0.6	0.953	0.9	0.946	0.6	0.927	0.9	0.929	1.4
1865	1.000	0.6	0.994	0.6	0.974	0.7	0.960	0.7	0.956	0.9	0.947	0.5	0.926	0.9	0.913	1.4
1870	1.000	0.5	0.961	0.8	0.947	0.8	0.945	0.7	0.949	1.1	0.943	0.6	0.920	0.9	0.925	1.6
1875	1.000	0.5	0.964	0.5	0.958	0.8	0.948	0.6	0.956	1.0	0.938	0.6	0.925	0.7	0.950	1.4
1880	1.000	0.5	0.967	0.6	0.956	0.9	0.945	0.8	0.953	1.1	0.946	0.7	0.923	0.8	0.929	1.4
1885	1.000	0.5	0.955	0.4	0.963	1.0	0.955	0.7	0.975	1.2	0.972	0.7	0.944	1.0	0.942	1.5
1890	1.000	0.7	0.958	0.6	0.946	0.9	0.925	0.6	0.948	1.2	0.942	0.7	0.924	0.5	0.917	1.5
1895	1.000	0.6	0.969	0.6	0.969	0.8	0.944	0.6	0.947	1.1	0.933	0.7	0.906	0.9	0.923	1.4
1900	1.000	0.6	0.976	0.5	0.978	0.8	0.967	0.6	0.974	1.2	0.957	0.6	0.926	0.9	0.933	1.5
1905	1.000	0.7	0.972	0.5	0.971	1.0	0.968	0.8	0.965	1.1	0.960	0.7	0.931	0.8	0.932	1.6
1910	1.000	0.7	0.965	0.6	0.960	0.9	0.956	0.8	0.961	1.2	0.964	0.8	0.939	0.8	0.920	1.5
1915	1.000	0.6	0.972	0.6	0.957	0.8	0.940	0.8	0.959	1.3	0.931	0.9	0.908	0.9	0.899	1.5
1920	1.000	0.5	0.971	0.6	0.953	0.7	0.938	0.6	0.942	1.2	0.923	0.6	0.902	0.8	0.893	1.4
1925	1.000	0.6	0.955	0.5	0.938	0.7	0.926	0.8	0.944	1.3	0.936	0.7	0.911	1.1	0.909	1.5
1930	1.000	0.7	0.973	0.5	0.956	0.6	0.939	0.8	0.910	1.2	0.909	0.8	0.898	1.0	0.902	1.4
1935	1.000	0.7	0.973	0.7	0.963	0.7	0.963	0.8	0.957	1.3	0.949	0.8	0.929	1.0	0.951	1.4
1940	1.000	0.7	0.968	0.6	0.951	0.9	0.955	0.6	0.953	1.3	0.946	0.6	0.915	1.0	0.920	1.4
1945	1.000	0.4	0.972	0.6	0.945	0.9	0.940	0.5	0.922	1.2	0.914	0.7	0.890	1.0	0.877	1.4
1950	1.000	0.6	0.958	0.5	0.948	0.6	0.944	0.8	0.939	1.3	0.931	0.7	0.905	0.9	0.887	1.5
1955	1.000	0.6	0.965	0.6	0.953	0.5	0.940	0.7	0.933	1.2	0.932	0.8	0.904	0.7	0.898	1.5
1960	1.000	0.6	0.971	0.5	0.973	0.9	0.952	0.6	0.944	1.3	0.932	0.7	0.900	0.9	0.908	1.4
1965	1.000	0.5	0.978	0.4	0.986	0.9	0.968	0.8	0.960	1.2	0.945	0.7	0.912	1.0	0.931	1.4
1970	1.000	0.6	0.984	0.4	0.960	0.8	0.948	0.8	0.939	1.4	0.937	0.8	0.905	1.0	0.920	1.4

TABLE 2c

SENSITIVITY CHANGES - LARGE APERTURE

	t=1978.89		t=1979.88		t=1980.85		t=1981.80		t=1982.83		t=1983.91		t=1984.91		t=1985.87	
λ (Å)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)
1150	1.000	1.8	1.033	1.6	1.043	2.1	1.030	1.2	1.014	1.0	0.955	1.2	0.935	1.0	0.910	1.1
1155	1.000	1.0	1.010	1.1	0.950	1.5	0.927	1.3	0.851	0.8	0.783	1.0	0.784	1.0	0.788	0.9
1160	1.000	0.9	1.005	0.7	0.989	1.3	0.928	1.2	0.888	0.8	0.831	0.8	0.821	0.8	0.830	0.8
1165	1.000	0.6	0.986	0.8	0.954	1.2	0.930	0.9	0.893	0.7	0.844	0.6	0.846	0.7	0.830	0.7
1170	1.000	0.7	0.993	0.6	0.972	1.0	0.964	0.7	0.923	0.5	0.861	0.7	0.853	0.6	0.841	0.7
1175	1.000	1.0	0.989	0.9	0.963	1.1	0.910	0.9	0.881	0.8	0.847	0.7	0.834	0.7	0.845	0.7
1180	1.000	0.9	1.006	0.5	1.000	1.0	0.958	0.9	0.932	0.6	0.879	0.7	0.903	0.5	0.879	0.7
1185	1.000	0.8	1.008	0.7	0.975	0.9	0.942	0.8	0.927	0.6	0.882	0.7	0.898	0.5	0.874	0.6
1190	1.000	0.9	1.010	0.7	0.988	0.8	0.944	1.1	0.908	0.8	0.879	0.6	0.901	0.6	0.891	0.6
1195	1.000	1.4	0.997	0.8	0.992	0.5	0.978	1.0	0.938	0.6	0.905	0.5	0.910	0.7	0.889	0.5
1200	1.000	0.7	1.014	0.8	1.025	0.7	1.009	1.2	0.974	0.4	0.920	0.5	0.926	0.7	0.902	0.7
1205	1.000	0.8	0.977	0.7	0.982	0.7	0.977	0.7	0.939	0.5	0.910	0.4	0.912	0.6	0.891	0.6
1210	1.000	2.1	0.994	2.0	0.990	1.7	0.988	2.5	0.987	1.6	0.996	0.5	0.971	1.1	0.899	1.2
1215	1.000	1.4	0.996	1.7	0.978	3.4	0.941	3.5	0.868	1.0	0.834	0.9	0.833	1.3	0.833	1.6
1220	1.000	2.1	1.001	0.8	1.017	2.3	0.959	2.9	0.950	1.0	0.872	1.6	0.907	1.3	0.926	1.4
1225	1.000	0.5	0.988	0.4	0.988	0.7	0.972	0.5	0.951	0.5	0.934	0.5	0.948	0.6	0.927	0.5
1230	1.000	0.4	0.985	0.5	0.974	0.5	0.957	0.5	0.929	0.5	0.914	0.4	0.922	0.5	0.913	0.5
1235	1.000	0.5	1.011	0.6	0.983	0.6	0.979	0.4	0.940	0.5	0.927	0.4	0.909	0.5	0.907	0.4
1240	1.000	0.5	1.000	0.6	0.999	0.7	0.976	0.4	0.940	0.4	0.924	0.4	0.924	0.4	0.911	0.5
1245	1.000	0.5	0.990	0.5	0.982	0.6	1.004	0.5	0.983	0.4	0.966	0.4	0.973	0.4	0.957	0.5
1250	1.000	0.5	0.997	0.4	0.989	0.4	0.983	0.4	0.959	0.4	0.954	0.4	0.964	0.4	0.965	0.3
1255	1.000	0.4	0.997	0.4	0.999	0.5	1.019	0.5	1.002	0.2	0.994	0.4	0.994	0.4	0.976	0.5
1260	1.000	0.4	1.024	0.5	1.036	0.5	1.017	0.5	1.003	0.3	0.977	0.4	0.990	0.4	0.989	0.5
1265	1.000	0.6	1.001	0.4	0.985	0.5	0.976	0.4	0.969	0.5	0.966	0.4	0.972	0.4	0.963	0.5
1270	1.000	0.4	0.994	0.4	0.984	0.4	0.987	0.4	0.953	0.5	0.954	0.3	0.974	0.3	0.956	0.4
1275	1.000	0.4	0.988	0.4	0.974	0.4	0.977	0.4	0.954	0.5	0.944	0.3	0.961	0.4	0.952	0.4
1280	1.000	0.4	0.987	0.4	0.992	0.4	1.010	0.5	0.985	0.5	0.961	0.4	0.965	0.3	0.955	0.4
1285	1.000	0.4	1.002	0.3	1.002	0.5	1.014	0.5	0.993	0.5	0.984	0.3	0.990	0.4	0.979	0.4
1290	1.000	0.4	0.995	0.4	0.980	0.4	1.028	0.5	1.006	0.4	1.005	0.4	1.015	0.4	0.997	0.5
1295	1.000	0.5	0.971	0.5	0.978	0.6	0.976	0.5	0.966	0.4	0.969	0.5	0.980	0.4	0.954	0.5
1300	1.000	0.4	1.007	0.5	1.013	0.4	0.998	0.5	0.986	0.3	0.982	0.4	0.988	0.4	0.965	0.5
1305	1.000	0.6	1.015	0.5	1.000	0.7	0.986	0.6	0.963	0.5	0.970	0.4	0.979	0.5	0.963	0.4
1310	1.000	0.5	0.990	0.5	0.988	0.4	0.981	0.7	0.962	0.5	0.943	0.5	0.963	0.4	0.954	0.5
1315	1.000	0.4	0.992	0.5	0.992	0.5	0.983	0.4	0.961	0.4	0.958	0.4	0.961	0.4	0.939	0.4
1320	1.000	0.4	0.970	0.5	0.974	0.6	0.994	0.5	0.973	0.5	0.961	0.4	0.968	0.5	0.934	0.4
1325	1.000	0.4	0.988	0.5	0.991	0.6	0.989	0.4	0.956	0.3	0.951	0.4	0.962	0.4	0.930	0.5
1330	1.000	0.5	0.962	0.5	0.971	0.6	0.990	0.6	0.967	0.4	0.966	0.4	0.970	0.4	0.941	0.6
1335	1.000	0.4	0.987	0.4	0.995	0.5	0.984	0.5	0.969	0.5	0.969	0.3	0.973	0.5	0.963	0.5
1340	1.000	0.5	0.983	0.4	0.980	0.4	0.969	0.5	0.955	0.5	0.946	0.4	0.953	0.3	0.947	0.4
1345	1.000	0.5	0.963	0.5	0.947	0.4	0.948	0.5	0.937	0.4	0.939	0.4	0.951	0.5	0.926	0.5
1350	1.000	0.3	0.978	0.4	0.989	0.5	0.979	0.4	0.958	0.4	0.950	0.4	0.966	0.4	0.953	0.5
1355	1.000	0.3	0.979	0.4	0.988	0.5	0.992	0.4	0.990	0.4	0.986	0.4	0.995	0.4	0.979	0.4
1360	1.000	0.5	0.973	0.5	0.996	0.5	1.006	0.5	0.987	0.4	0.974	0.5	0.988	0.5	0.954	0.5
1365	1.000	0.5	0.974	0.5	0.979	0.4	0.967	0.5	0.960	0.5	0.944	0.4	0.971	0.4	0.952	0.5
1370	1.000	0.4	0.987	0.5	0.994	0.5	1.011	0.5	0.964	0.4	0.951	0.4	0.953	0.4	0.931	0.6
1375	1.000	0.4	0.981	0.4	0.988	0.3	0.972	0.4	0.960	0.4	0.955	0.3	0.956	0.4	0.930	0.5
1380	1.000	0.4	0.950	0.5	0.949	0.5	0.939	0.4	0.942	0.4	0.939	0.3	0.939	0.4	0.931	0.4
1385	1.000	0.5	0.974	0.5	0.975	0.5	0.979	0.5	0.962	0.4	0.950	0.4	0.949	0.5	0.921	0.5
1390	1.000	0.5	0.957	0.6	0.952	0.7	0.979	0.6	0.960	0.5	0.949	0.4	0.953	0.5	0.928	0.5
1395	1.000	0.5	0.994	0.4	1.005	0.5	0.987	0.6	0.969	0.4	0.940	0.5	0.948	0.4	0.939	0.4
1400	1.000	0.5	0.956	0.4	0.946	0.5	0.943	0.5	0.929	0.5	0.922	0.5	0.929	0.4	0.894	0.5
1405	1.000	0.6	0.991	0.4	0.996	0.4	0.971	0.5	0.970	0.4	0.950	0.5	0.964	0.4	0.943	0.5
1410	1.000	0.4	0.960	0.5	0.965	0.4	0.985	0.6	0.971	0.4	0.947	0.4	0.951	0.5	0.942	0.6
1415	1.000	0.5	0.968	0.4	0.972	0.4	0.965	0.5	0.952	0.4	0.949	0.4	0.953	0.4	0.938	0.5
1420	1.000	0.4	0.981	0.4	0.990	0.5	0.958	0.6	0.937	0.4	0.925	0.5	0.928	0.4	0.910	0.5

TABLE 2c - *Continued*

SENSITIVITY CHANGES - LARGE APERTURE

λ (Å)	t=1978.89		t=1979.88		t=1980.85		t=1981.80		t=1982.83		t=1983.91		t=1984.91		t=1985.87	
	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)
1425	1.000	0.4	0.955	0.5	0.975	0.5	0.982	0.5	0.975	0.4	0.958	0.4	0.957	0.5	0.940	0.5
1430	1.000	0.5	0.982	0.5	0.967	0.5	0.962	0.5	0.944	0.4	0.916	0.4	0.916	0.5	0.901	0.5
1435	1.000	0.4	0.995	0.4	0.988	0.4	0.972	0.4	0.955	0.5	0.941	0.4	0.940	0.4	0.938	0.5
1440	1.000	0.5	0.979	0.4	0.967	0.4	0.954	0.5	0.937	0.4	0.927	0.4	0.927	0.5	0.911	0.6
1445	1.000	0.5	0.965	0.6	0.958	0.4	0.957	0.5	0.934	0.3	0.931	0.4	0.938	0.3	0.925	0.4
1450	1.000	0.4	0.948	0.5	0.962	0.4	0.962	0.5	0.963	0.6	0.958	0.4	0.966	0.4	0.942	0.4
1455	1.000	0.4	0.940	0.4	0.939	0.4	0.955	0.5	0.937	0.4	0.924	0.4	0.933	0.5	0.917	0.5
1460	1.000	0.4	0.967	0.4	0.965	0.5	0.957	0.4	0.937	0.5	0.934	0.4	0.946	0.4	0.940	0.5
1465	1.000	0.4	0.981	0.5	0.972	0.4	0.963	0.4	0.957	0.4	0.941	0.4	0.949	0.5	0.944	0.5
1470	1.000	0.5	0.957	0.5	0.958	0.5	0.963	0.5	0.964	0.4	0.950	0.4	0.960	0.3	0.952	0.4
1475	1.000	0.4	0.953	0.5	0.955	0.5	0.969	0.6	0.957	0.4	0.951	0.3	0.951	0.4	0.934	0.4
1480	1.000	0.4	0.947	0.6	0.946	0.5	0.938	0.4	0.948	0.5	0.935	0.4	0.938	0.5	0.932	0.4
1485	1.000	0.4	0.950	0.5	0.940	0.5	0.923	0.4	0.924	0.5	0.903	0.4	0.916	0.5	0.904	0.4
1490	1.000	0.4	0.982	0.5	0.956	0.5	0.949	0.5	0.935	0.5	0.913	0.4	0.921	0.4	0.918	0.5
1495	1.000	0.4	0.976	0.5	0.957	0.5	0.974	0.5	0.938	0.5	0.924	0.4	0.928	0.4	0.916	0.4
1500	1.000	0.4	0.969	0.4	0.961	0.5	0.976	0.5	0.950	0.4	0.957	0.4	0.961	0.5	0.932	0.5
1505	1.000	0.4	0.997	0.5	1.014	0.5	1.003	0.5	1.000	0.4	0.974	0.5	0.970	0.4	0.965	0.4
1510	1.000	0.5	0.958	0.4	0.970	0.5	0.972	0.5	0.980	0.5	0.962	0.4	0.968	0.4	0.938	0.5
1515	1.000	0.5	0.963	0.5	0.945	0.4	0.924	0.6	0.905	0.5	0.894	0.5	0.910	0.4	0.900	0.6
1520	1.000	0.4	0.990	0.5	0.980	0.6	0.979	0.5	0.979	0.5	0.971	0.5	0.985	0.5	0.975	0.6
1525	1.000	0.5	0.951	0.6	0.950	0.5	0.960	0.6	0.960	0.5	0.937	0.4	0.935	0.4	0.914	0.5
1530	1.000	0.5	0.968	0.4	0.964	0.5	0.966	0.6	0.964	0.4	0.963	0.5	0.959	0.5	0.948	0.4
1535	1.000	0.6	0.969	0.5	0.971	0.5	0.969	0.5	0.963	0.4	0.964	0.5	0.980	0.4	0.966	0.5
1540	1.000	0.5	0.992	0.5	0.970	0.4	0.975	0.5	0.967	0.5	0.975	0.5	0.970	0.5	0.969	0.5
1545	1.000	0.6	0.991	0.5	0.969	0.6	0.966	0.7	0.967	0.5	0.963	0.4	0.958	0.6	0.935	0.6
1550	1.000	0.6	1.012	0.5	1.019	0.6	1.009	0.7	1.010	0.5	0.985	0.5	0.989	0.5	0.977	0.5
1555	1.000	0.7	1.001	0.5	0.994	0.6	0.997	0.7	1.009	0.6	0.988	0.4	1.003	0.5	0.981	0.6
1560	1.000	0.5	0.979	0.6	0.985	0.7	0.990	0.6	1.001	0.5	0.992	0.4	1.004	0.5	0.983	0.5
1565	1.000	0.5	1.017	0.4	1.021	0.5	1.015	0.5	1.015	0.5	1.008	0.5	1.038	0.4	1.024	0.5
1570	1.000	0.6	1.005	0.5	1.013	0.5	1.002	0.4	0.985	0.5	0.973	0.4	0.988	0.5	0.971	0.4
1575	1.000	0.5	0.986	0.4	0.984	0.5	0.999	0.5	0.975	0.5	0.970	0.4	0.968	0.6	0.961	0.5
1580	1.000	0.5	0.998	0.5	1.000	0.6	0.998	0.5	1.018	0.5	1.009	0.5	1.013	0.5	1.002	0.6
1585	1.000	0.4	0.994	0.5	0.987	0.5	1.001	0.5	1.010	0.4	0.995	0.5	0.997	0.5	0.994	0.5
1590	1.000	0.5	0.990	0.4	0.975	0.6	0.973	0.6	0.976	0.5	0.963	0.4	0.978	0.4	0.955	0.5
1595	1.000	0.5	0.987	0.5	0.971	0.5	0.979	0.5	0.976	0.5	0.968	0.5	0.987	0.4	0.976	0.5
1600	1.000	0.5	0.967	0.5	0.951	0.5	0.964	0.5	0.963	0.6	0.946	0.4	0.965	0.5	0.942	0.4
1605	1.000	0.6	0.963	0.6	0.966	0.6	0.973	0.4	0.957	0.5	0.949	0.4	0.968	0.5	0.948	0.6
1610	1.000	0.6	0.966	0.5	0.960	0.6	0.976	0.4	0.956	0.4	0.949	0.4	0.960	0.5	0.948	0.5
1615	1.000	0.6	1.014	0.5	1.004	0.5	0.978	0.6	0.975	0.6	0.968	0.5	0.989	0.5	0.974	0.5
1620	1.000	0.6	1.001	0.4	1.002	0.6	1.018	0.5	1.020	0.6	1.000	0.4	1.033	0.5	1.015	0.6
1625	1.000	0.5	0.998	0.4	1.003	0.6	1.023	0.5	1.015	0.5	0.980	0.5	0.992	0.4	0.977	0.5
1630	1.000	0.5	1.007	0.4	0.997	0.5	0.998	0.4	0.988	0.4	0.982	0.4	0.985	0.5	0.968	0.6
1635	1.000	0.6	0.994	0.5	1.011	0.6	1.021	0.5	1.031	0.5	1.032	0.4	1.048	0.5	1.037	0.6
1640	1.000	0.5	0.976	0.4	0.975	0.5	0.959	0.4	0.969	0.4	0.967	0.5	0.980	0.4	0.970	0.6
1645	1.000	0.5	0.994	0.5	0.992	0.6	0.982	0.5	0.950	0.4	0.931	0.5	0.952	0.4	0.943	0.5
1650	1.000	0.5	0.985	0.4	0.999	0.5	1.005	0.5	0.988	0.5	0.959	0.4	0.968	0.5	0.959	0.5
1655	1.000	0.5	0.990	0.5	0.973	0.4	0.981	0.4	0.974	0.4	0.977	0.5	0.976	0.4	0.969	0.6
1660	1.000	0.5	0.982	0.4	0.981	0.5	0.971	0.5	0.981	0.5	0.962	0.4	0.978	0.4	0.972	0.5
1665	1.000	0.5	0.983	0.4	0.999	0.5	1.020	0.6	1.019	0.5	1.012	0.4	1.025	0.5	0.997	0.4
1670	1.000	0.5	0.991	0.4	0.993	0.4	0.980	0.4	0.988	0.5	0.977	0.4	0.990	0.4	0.969	0.5
1675	1.000	0.6	0.989	0.4	1.006	0.5	0.991	0.6	0.993	0.5	0.978	0.4	0.986	0.6	0.965	0.4
1680	1.000	0.5	1.007	0.4	1.009	0.4	1.020	0.6	1.011	0.4	0.992	0.4	1.008	0.4	0.985	0.4
1685	1.000	0.5	1.018	0.4	1.008	0.5	1.020	0.4	1.021	0.4	1.013	0.4	1.024	0.4	1.005	0.5
1690	1.000	0.5	0.985	0.4	0.986	0.5	0.990	0.4	0.977	0.4	0.973	0.4	0.982	0.4	0.960	0.5
1695	1.000	0.4	0.977	0.4	0.976	0.5	0.961	0.5	0.947	0.4	0.937	0.4	0.945	0.5	0.941	0.4

TABLE 2c - *Continued*

SENSITIVITY CHANGES - LARGE APERTURE

	t=1978.89		t=1979.88		t=1980.85		t=1981.80		t=1982.83		t=1983.91		t=1984.91		t=1985.87	
λ (Å)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)	f(t)	σ(%)
1700	1.000	0.4	0.993	0.5	0.984	0.5	0.982	0.4	0.991	0.5	0.970	0.4	0.970	0.3	0.967	0.5
1705	1.000	0.5	0.970	0.4	0.974	0.4	0.977	0.5	0.970	0.4	0.963	0.5	0.968	0.4	0.959	0.4
1710	1.000	0.4	0.989	0.5	0.991	0.5	0.986	0.6	0.976	0.3	0.978	0.4	0.989	0.4	0.967	0.4
1715	1.000	0.4	0.978	0.5	0.985	0.5	0.999	0.5	0.996	0.5	0.989	0.5	0.993	0.4	0.969	0.5
1720	1.000	0.5	0.977	0.4	0.959	0.5	0.957	0.5	0.950	0.6	0.932	0.5	0.942	0.5	0.923	0.5
1725	1.000	0.6	0.992	0.5	0.988	0.6	0.975	0.4	0.981	0.5	0.944	0.5	0.953	0.4	0.940	0.5
1730	1.000	0.5	0.981	0.4	0.963	0.4	0.951	0.5	0.944	0.4	0.916	0.4	0.927	0.5	0.914	0.5
1735	1.000	0.4	0.979	0.4	0.974	0.5	0.972	0.5	0.967	0.5	0.953	0.4	0.956	0.4	0.946	0.4
1740	1.000	0.4	0.967	0.5	0.963	0.5	0.974	0.5	0.965	0.4	0.947	0.4	0.952	0.3	0.951	0.3
1745	1.000	0.5	0.984	0.4	0.976	0.4	0.955	0.5	0.951	0.4	0.934	0.4	0.947	0.3	0.921	0.6
1750	1.000	0.4	0.993	0.4	1.009	0.5	0.992	0.5	0.984	0.4	0.965	0.3	0.972	0.4	0.957	0.5
1755	1.000	0.4	0.974	0.4	0.963	0.3	0.959	0.5	0.960	0.4	0.945	0.4	0.950	0.4	0.944	0.5
1760	1.000	0.4	0.963	0.4	0.952	0.3	0.938	0.4	0.920	0.4	0.918	0.3	0.924	0.3	0.909	0.4
1765	1.000	0.4	0.966	0.4	0.952	0.4	0.960	0.6	0.945	0.3	0.926	0.4	0.933	0.3	0.914	0.4
1770	1.000	0.5	0.951	0.4	0.930	0.4	0.932	0.4	0.919	0.5	0.907	0.4	0.907	0.4	0.892	0.4
1775	1.000	0.5	0.959	0.5	0.958	0.4	0.958	0.4	0.952	0.4	0.939	0.4	0.954	0.4	0.935	0.5
1780	1.000	0.5	0.966	0.4	0.977	0.4	0.991	0.5	0.971	0.4	0.971	0.4	0.984	0.3	0.972	0.4
1785	1.000	0.4	0.961	0.4	0.951	0.4	0.956	0.5	0.961	0.4	0.960	0.3	0.963	0.4	0.953	0.4
1790	1.000	0.4	0.963	0.3	0.956	0.4	0.941	0.4	0.935	0.4	0.931	0.3	0.939	0.3	0.933	0.4
1795	1.000	0.4	0.957	0.3	0.935	0.5	0.920	0.5	0.930	0.4	0.917	0.3	0.928	0.3	0.927	0.4
1800	1.000	0.4	0.966	0.4	0.971	0.4	0.968	0.5	0.948	0.4	0.939	0.4	0.945	0.4	0.943	0.4
1805	1.000	0.4	0.978	0.3	0.963	0.4	0.961	0.5	0.948	0.4	0.943	0.3	0.945	0.3	0.925	0.4
1810	1.000	0.4	0.969	0.3	0.952	0.4	0.956	0.4	0.940	0.4	0.934	0.3	0.934	0.3	0.922	0.4
1815	1.000	0.5	0.968	0.3	0.946	0.5	0.933	0.5	0.926	0.4	0.904	0.4	0.915	0.4	0.903	0.5
1820	1.000	0.4	0.959	0.4	0.945	0.4	0.932	0.5	0.910	0.4	0.901	0.4	0.903	0.3	0.884	0.3
1825	1.000	0.4	0.966	0.4	0.974	0.4	0.987	0.5	0.977	0.4	0.955	0.3	0.950	0.4	0.936	0.4
1830	1.000	0.4	0.969	0.4	0.965	0.4	0.959	0.5	0.958	0.3	0.950	0.3	0.955	0.4	0.942	0.4
1835	1.000	0.4	0.965	0.4	0.976	0.4	0.971	0.4	0.958	0.3	0.942	0.3	0.950	0.4	0.926	0.4
1840	1.000	0.4	0.963	0.5	0.967	0.4	0.962	0.4	0.959	0.4	0.949	0.3	0.948	0.4	0.918	0.4
1845	1.000	0.5	0.971	0.4	0.961	0.4	0.952	0.5	0.948	0.4	0.934	0.4	0.934	0.4	0.918	0.5
1850	1.000	0.5	0.976	0.5	0.979	0.5	0.968	0.5	0.962	0.3	0.950	0.4	0.954	0.3	0.927	0.5
1855	1.000	0.5	0.983	0.4	0.972	0.5	0.957	0.5	0.951	0.4	0.943	0.4	0.942	0.3	0.930	0.4
1860	1.000	0.5	0.971	0.4	0.953	0.4	0.948	0.3	0.941	0.3	0.934	0.4	0.941	0.4	0.927	0.5
1865	1.000	0.4	0.970	0.4	0.960	0.4	0.935	0.4	0.933	0.4	0.922	0.4	0.924	0.4	0.913	0.4
1870	1.000	0.4	0.950	0.4	0.947	0.4	0.957	0.5	0.945	0.4	0.924	0.3	0.934	0.4	0.892	0.4
1875	1.000	0.4	0.959	0.4	0.954	0.4	0.950	0.4	0.948	0.4	0.938	0.3	0.945	0.4	0.928	0.4
1880	1.000	0.4	0.970	0.4	0.951	0.3	0.948	0.4	0.938	0.3	0.925	0.4	0.930	0.4	0.905	0.5
1885	1.000	0.4	0.971	0.4	0.966	0.3	0.965	0.5	0.955	0.4	0.956	0.3	0.957	0.4	0.927	0.4
1890	1.000	0.5	0.968	0.5	0.966	0.4	0.954	0.5	0.934	0.4	0.926	0.4	0.930	0.4	0.902	0.5
1895	1.000	0.4	0.966	0.5	0.964	0.5	0.952	0.5	0.940	0.4	0.923	0.3	0.928	0.4	0.904	0.4
1900	1.000	0.5	0.957	0.5	0.955	0.5	0.963	0.4	0.956	0.5	0.942	0.4	0.954	0.4	0.925	0.4
1905	1.000	0.5	0.976	0.4	0.958	0.4	0.951	0.5	0.931	0.5	0.938	0.4	0.941	0.3	0.933	0.4
1910	1.000	0.5	0.983	0.4	0.967	0.4	0.958	0.4	0.939	0.4	0.932	0.3	0.934	0.3	0.915	0.5
1915	1.000	0.4	0.976	0.4	0.962	0.4	0.961	0.5	0.946	0.4	0.935	0.3	0.934	0.4	0.911	0.5
1920	1.000	0.4	0.979	0.4	0.952	0.4	0.919	0.4	0.914	0.4	0.913	0.3	0.910	0.3	0.895	0.4
1925	1.000	0.4	0.974	0.4	0.947	0.4	0.905	0.5	0.891	0.4	0.890	0.4	0.887	0.3	0.874	0.4
1930	1.000	0.4	0.977	0.4	0.953	0.4	0.916	0.4	0.902	0.5	0.884	0.4	0.885	0.3	0.878	0.4
1935	1.000	0.4	0.978	0.4	0.966	0.4	0.967	0.3	0.955	0.3	0.928	0.4	0.926	0.4	0.907	0.4
1940	1.000	0.4	0.981	0.4	0.975	0.4	0.975	0.4	0.944	0.3	0.932	0.4	0.929	0.4	0.913	0.4
1945	1.000	0.4	0.968	0.4	0.962	0.3	0.962	0.5	0.941	0.4	0.931	0.4	0.934	0.4	0.907	0.4
1950	1.000	0.3	0.983	0.4	0.965	0.4	0.953	0.5	0.936	0.4	0.930	0.5	0.931	0.4	0.907	0.4
1955	1.000	0.4	1.010	0.4	0.978	0.4	0.960	0.5	0.940	0.4	0.917	0.3	0.907	0.4	0.888	0.4
1960	1.000	0.5	1.044	0.4	1.013	0.3	0.987	0.5	0.977	0.4	0.949	0.3	0.952	0.3	0.940	0.4
1965	1.000	0.7	1.053	0.9	0.969	0.6	0.936	0.5	0.934	0.5	0.931	0.4	0.932	0.4	0.922	0.4
1970	1.000	0.7	1.089	1.1	0.983	0.7	0.933	0.5	0.929	0.5	0.909	0.4	0.915	0.4	0.903	0.4

TABLE 3

MASKED WAVELENGTHS

Wavelength (Å)	Star	Aperture Mode	Justification
1175	BD+33°2642	S, L	Large sigma
1185-1200	HD60753 BD+33°2642	T, L	Reseau in wing of Lα
1205, 1225	HD60753 BD+33°2642	T, S, L	Steep sides of wide Lα
1210-1220	HD60753 HD93521 BD+33°2642 BD+28°4211	T, S, L	Lα
1240	HD93521	T, S, L	P-Cygni profile of NV
1315-1325	HD60753	T	Reseau between 2 strong lines
1545-1555	HD93521	T, S, L	P-Cygni profile of CIV

FIGURE CAPTIONS

Fig. 1 - Sensitivity changes in selected 5 Å bins for the mean of all five standard stars, showing the extremes of sensitivity decrease and increase, as well as some typical trends. In particular, note the opposite trends for the adjacent points at 1635 Å and 1640 Å. The error bars are the formal error in the mean. Trends for the small aperture and trailed aperture are generally similar to the large aperture but differ in detail.

Fig. 2 - Mean ratio of the five standard stars in 1985 to the baseline 1978 fluxes in 5 Å bins, before and after correction for the change in sensitivity. The error bars are the one-sigma scatter among the five individual ratios. The large glitch near the strong Lα absorption is caused by the division of fluxes that approach zero and by small wavelength errors that have a large effect on the 5 Å bins in the steep sides of Lα. The mean ratio from 1230 to 1970 Å is 0.929 before correction and 1.000 after correction. The rms scatter in the corrected average values is 0.8% and is indicative of the limiting accuracy of the technique, as applied to large samples of spectra. The mean rms scatter of 1.9% among the five individual ratios is the average length of the error bars and is indicative of the photometric error for a 5 Å bin in the mean spectrum for any one star. The ratio of the two mean error bars of 1.9 and 0.8% is nearly $\sqrt{5}$, as expected. The number of spectra in parentheses follow each star for 1978 and 1985, respectively: HD60753 (41, 20), BD+75°325 (28, 30), HD93521 (34, 11), BD+33°2642 (15, 6), and BD+28°4211 (24, 19).

Fig. 3 - Mean ratios of the spectra of two standard stars, HD60753 (15 spectra) and BD+28°4211 (15 spectra), obtained in 1986 to the baseline fluxes, as in Figure 2. The 1986 spectra are not used in deriving the correction, since all the numerator spectra were obtained after 1986.36. Even though extrapolation from the previous two years is required to correct this independent data set, the mean ratio of 0.914 is corrected to 1.002 with an rms scatter of 1.7% about the mean for the 5 Å bins longward of 1230 Å. The dip near 1800 Å is probably caused by interpolation across the reseau in the 1986 large aperture spectra. The only year that has no small aperture spectra to fill in this reseau position is 1986.

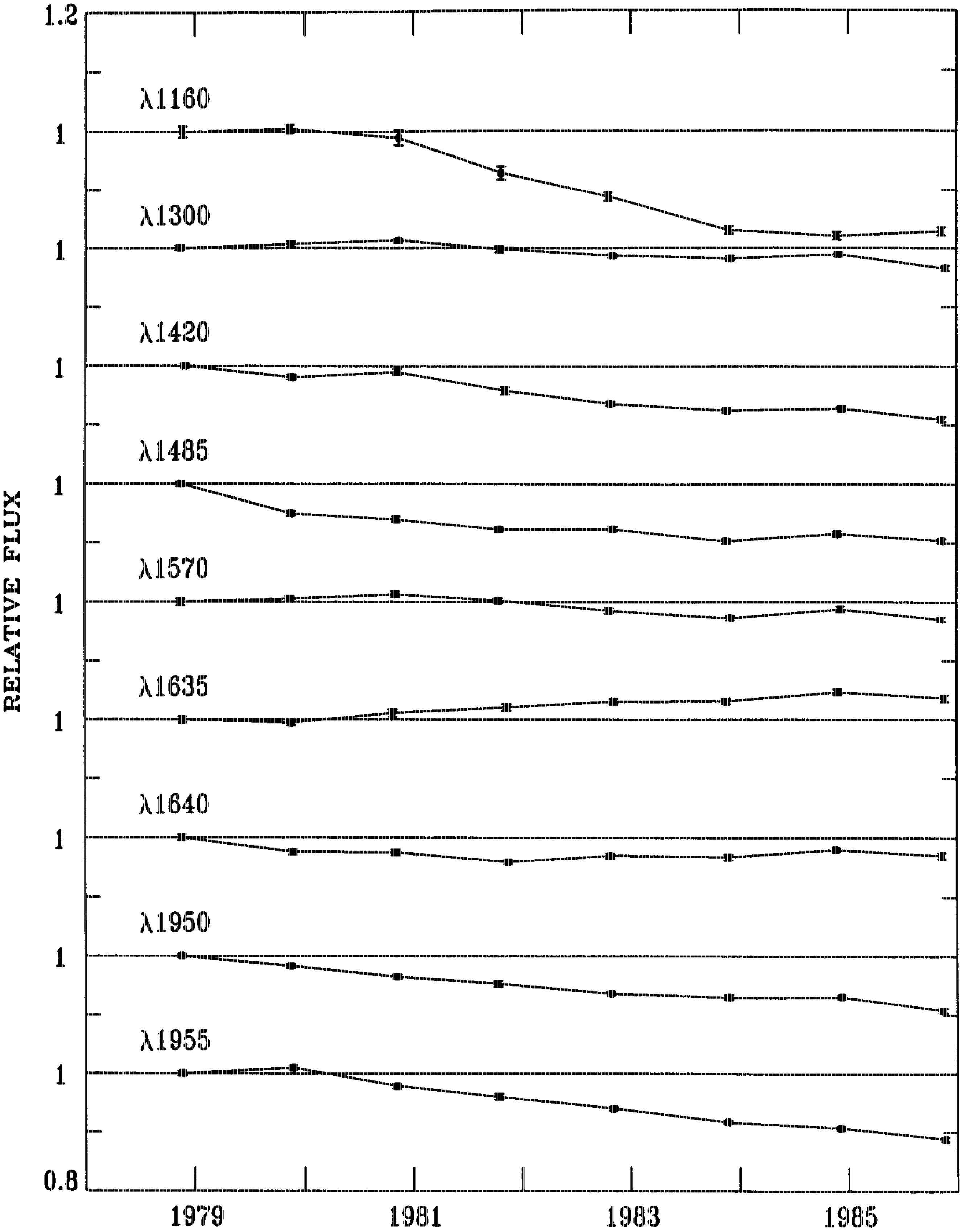
1.2
λ1160
1
λ1300
1
λ1420
1
λ1485
1
λ1570
1
λ1635
1
λ1640
1
λ1950
1
λ1955
1
0.8
RELATIVE FLUX
1979
1981
1983
1985
YEAR

Fig. 1

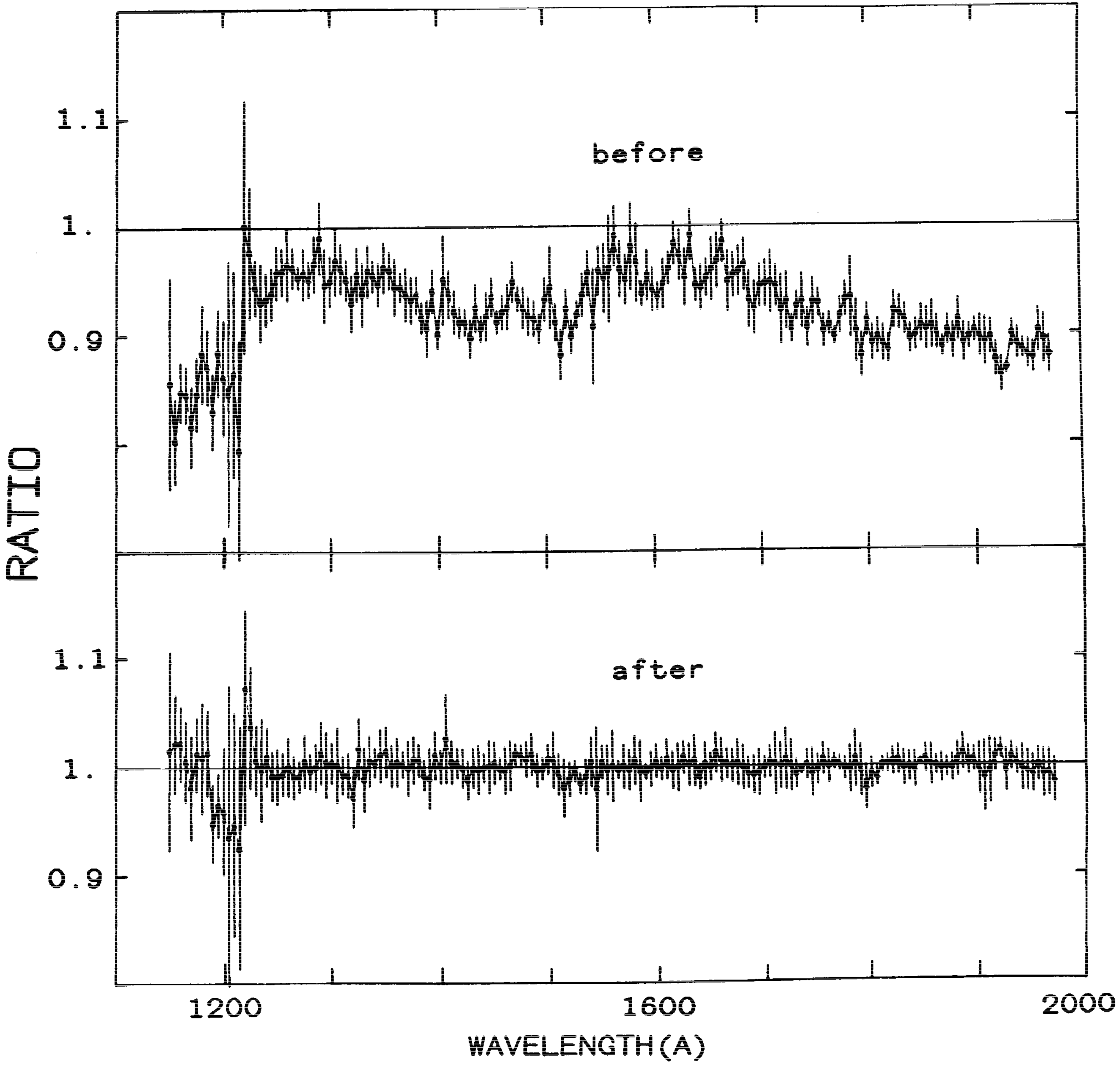

Fig. 2

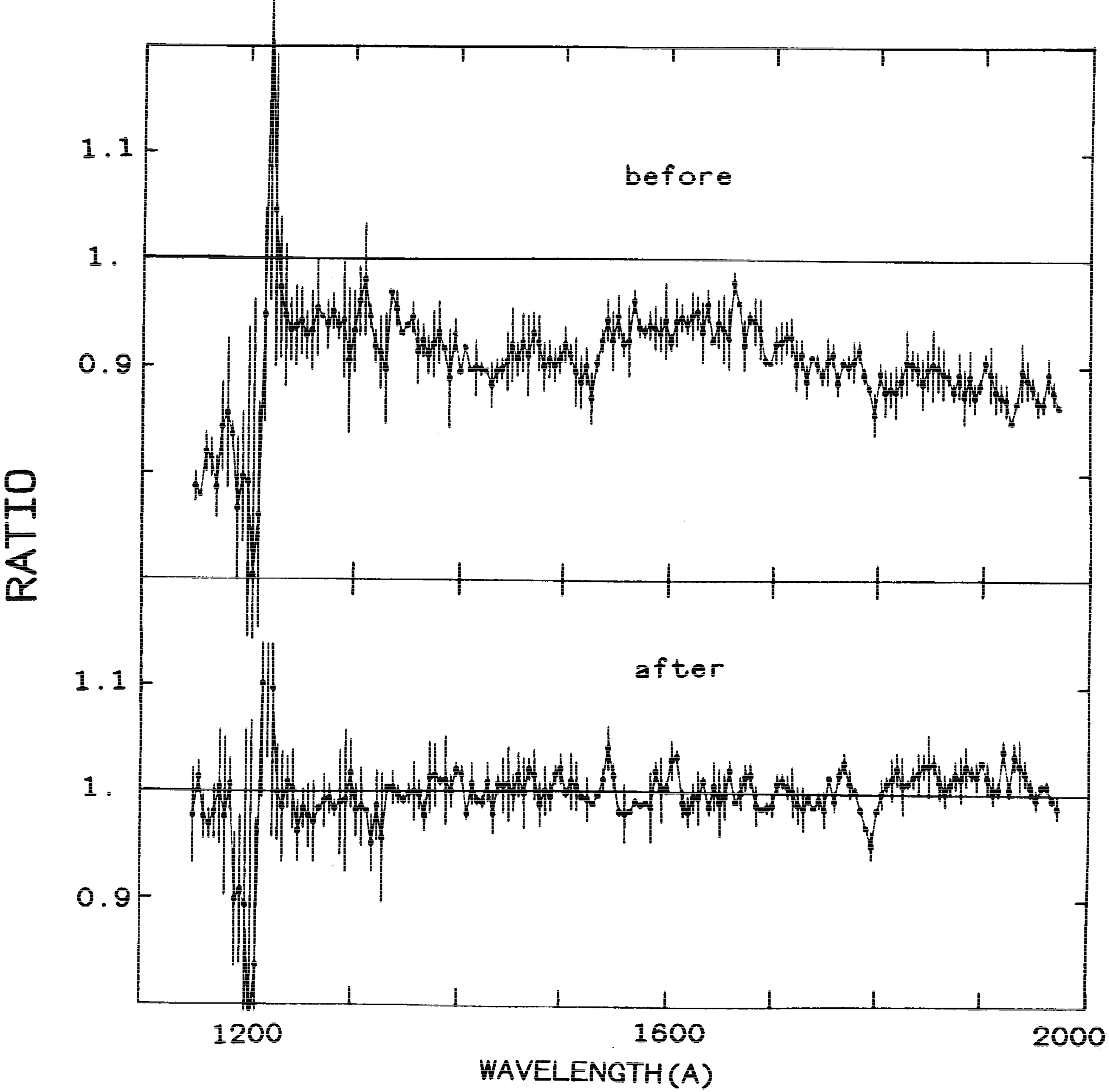

Fig. 3

APPENDIX A

```
      SUBROUTINE TCHANG(NPTS,YR,ICAM,IAPER,WL,ABSPEC)
C
CORRECT FOR TIME CHANGE OF IUE LO-DISP SENSITIVITY. 86-JUN-19  RCB
C INPUT:  NPTS-NUMBER OF POINTS IN THE WL AND ABSPEC ARRAYS.
C         YR-TIME OF OBSERVATION, EG. 78.147 MEANS 1978.147
C         ICAM-1(LWP), 2(LWR), 3(SWP)
C         IAPER-OBSERVING MODE 1,2,OR 3. SEE TCORR BELOW.
C         WL-WAVELENGTH ARRAY OF THE SPECTRUM
C         ABSPEC-ORIGINAL FLUX ARRAY OF THE SPECTRUM
C  OUTPUT: ABSPEC-FLUX VALUES CORRECTED FOR CHANGE IN SENSITIVITY.
C  SUBROUTINE CALLED:  FUNCTION WS2-TO FIND THE POINT NUMBER IN THE WL
C                           ARRAY FOR A SPECIFIED WAVELENGTH.
C
C TCORR SUBSCRIPTS ARE 1) MAX NO. OF POINTS OF 5A WL BINS.
C      2)APERTURE(IAPER): 1=TRAIL, 2=SMALL, 3=LARGE PT. SOURCE
C      3) CAMERA NUMBER 1,2, OR 3.
C      4) YEAR BIN (1 THRU NYR)
C
      DIMENSION WLC(301),CORR(301),WL(1022),ABSPEC(1022),
     +     TCORR(301,3,3,8),YRCORR(3,3,8)
      CHARACTER*5 AP(3)
      DATA AP/'TRAIL','SMALL','LARGE'/
C
C INITIALIZE THE CORRECTION ARRAYS AND READ IN CORRECTION DATA
C   (STATEMEMT NUMBER 90 BELOW) ON THE FIRST CALL TO THIS SUBROUTINE.
C   THE DATA FILE REFERRED TO BY THE READ CAN BE PROVIDED ON REQUEST
C   OVER THE SPAN NETWORK OR VIA COMPUTER MAIL.
C
      DATA ISTSW/0/
          IF(ISTSW.NE.0)GO TO 200
C
C NYR=NUMBER OF YEARS OF CORRECTIONS CURRENTLY INCLUDED.
C
          NYR=8
          ISTSW=1
          DO 50 I=1,301
          DO 50 J=1,3
          DO 50 K=1,3
          DO 50 L=1,NYR
50        TCORR(I,J,K,L)=0.
C
90        READ(29,100,END=200)JPTS,JAPER,JCAM,JYR,YRCORR(JAPER,JCAM,JYR)
100       FORMAT(4I4,F12.3)
          YRCORR(JAPER,JCAM,JYR)=YRCORR(JAPER,JCAM,JYR)-1900.
          READ(29,110)(TCORR(I,JAPER,JCAM,JYR),I=1,JPTS)
110       FORMAT(12F6.3)
C         WRITE(6,100)JPTS,JAPER,JCAM,JYR,YRCORR(JAPER,JCAM,JYR)
C         WRITE(6,110)(TCORR(I,JAPER,JCAM,JYR),I=1,JPTS)
          GO TO 90
C
COMPUTE WL SCALE
C
200   CLOSE(UNIT=29)
      JPTS=165
      WL1=1145
          IF(ICAM.LT.3)THEN
```

```
          JPTS=301
          WL1=1845.
          ENDIF
C
          DO 250 I=1,JPTS
250       WLC(I)=WL1+5.*I
C
C FIND PROPER WL RANGE FOR CORRECTION
C
          DO 300 I=1,NPTS
          IF(WL(I).LT.WLC(1)-2.5)ISTPT=I
          IF(WL(I).LE.WLC(JPTS)+2.5)LSTPT=I
300       CONTINUE
       ISTPT=ISTPT+1
      WRITE(6,310)WL(ISTPT),WL(LSTPT),YR,AP(IAPER)
310   FORMAT(' CORRECT FOR LOSS OF SENSITIVITY WITH TIME OVER RANGE:',
     +      2F8.1,' AT TIME=',F8.3,' FOR APERTURE=',A5,',',/
     +      ' ACCORDING TO BOHLIN AND GRILLMAIR (1988,AP.J.SUPPL.)')
C
CHECK PROPER YEAR
C
          IF(YR.LT.78..OR.YR.GT.90.)THEN
          WRITE(6,325)YR
325       FORMAT(F8.3,'=IMPROPER YEAR FOR TIME CORRECTION IN TCHANG')
          STOP 325
          ENDIF
C
C INTERPOLATE CORR. TO TIME=YR
C
400       DO 410 I=1,NYR-1
          II=I
          IF(YR.LT.YRCORR(IAPER,ICAM,I+1))GO TO 420
410       CONTINUE
          WRITE(6,415)YR
415       FORMAT(' TIME CORRECTION EXTRAPOLATED TO',F8.3)
420    IYR=II
      FRAC=(YR-YRCORR(IAPER,ICAM,IYR))/(YRCORR(IAPER,ICAM,IYR+1)
     +                                  -YRCORR(IAPER,ICAM,IYR))
          DO 450 I=1,JPTS
              IF(TCORR(I,IAPER,ICAM,IYR).EQ.0.  .OR.
     +            TCORR(I,IAPER,ICAM,IYR+1).EQ.0.)THEN
              WRITE(6,440)YR,WLC(I),AP(IAPER),ICAM
440           FORMAT(' EDIT ZERO TIME CORRECTION FOR YR,WL,APER,',
     +            'AND CAMERA=',F6.2,F7.1,A6,I3)
              STOP 440
              ENDIF
450       CORR(I)=TCORR(I,IAPER,ICAM,IYR)+
     +    (TCORR(I,IAPER,ICAM,IYR+1)-TCORR(I,IAPER,ICAM,IYR))*FRAC
C
C APPLY CORR. TO DATA USING NEAREST NEIGHBOR
C
          DO 520 I=ISTPT,LSTPT
              IF(WL(I).GT.WLC(1)-2.5.AND.WL(I).LT.WLC(1))THEN
              N=1
              GO TO 490
              ENDIF
              IF(WL(I).GT.WLC(JPTS).AND.WL(I).LT.WLC(JPTS)+2.5)THEN
              N=JPTS
              GO TO 490
              ENDIF
```

```
          N=WS2(WL(I),JPTS,WLC)+0.5
490           IF(CORR(N).LE.0.)THEN
              WRITE(6,500)N,WLC(N),CORR(N)
500           FORMAT(' TIME CORR. IN TCHANG SUBROUTINE IS OUT OF',
     +                ' RANGE AT',I5,2F8.2)
              STOP 500
              ENDIF
520       ABSPEC(I)=ABSPEC(I)/CORR(N)
      RETURN
      END
      FUNCTION WS2(WLN,NPTS,WL)
C
C  FIND THE POINT, WS2, IN THE WAVELENGTH ARRAY, WL, THAT CORRESPONDS TO
C      THE WAVELENGTH WLN, USING A BINARY SEARCH.
C  INPUT:  WLN
C          NPTS-NUMBER OF POINTS IN THE WL ARRAY
C          WL
C  OUTPUT: WS2
C
      REAL*4 WL(1)
      IF(WLN .LT. WL(1))GO TO 100
      IF(WLN .LE. WL(NPTS))GO TO 200
100   WRITE(6,101)WLN
101   FORMAT(' WAVELENGTH OUT OF RANGE',F10.3)
      STOP 100
200   DEL=NPTS
       SGN=1.
      AT=0.
210   DEL=DEL/2.
      AT=AT+SGN*DEL
      IAT=AT+.5
      SGN=+1.
      IF(WL(IAT) .GT. WLN)SGN=-1.
      IF(DEL .GT. 1.)GO TO 210
      ISGN=SGN
      IF(WL(IAT).EQ.WL(IAT+ISGN))IAT=IAT+ISGN
      AT=IAT
      NXT=IAT+ISGN
      WAT=WL(IAT)
      WS2=((WLN-WAT)/(WL(NXT)-WAT))*SGN+AT
      RETURN
      END
```