Linearity of Low Dispersion Trailed Spectra Processed with the New LWP ITF

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I. Introduction

On September 24-28, 1984, the observations for a new LWP ITF (ITF2) were obtained. Standard star spectra, processed with the new ITF, have been analyzed to study the reproducibility and linearity errors of non-optimum exposures. The observational and analysis techniques are briefly summarized in section II. The differences between optimum trailed spectra when processed with either ITF2 or ITF1 are discussed in section III. The linearity of non-optimum spectra obtained in September 1982, September 1984, and September 1985, is discussed in section IV. Finally, the linearity of spectra with high backgrounds is discussed in section IV.

II. Observation and Data Analysis Techniques

The observation and analysis techniques used for this study are similar to the method used in Oliversen (1983, 1984a and 1984b). The standard star HD 60753 is routinely observed for linearity monitoring twice per year. This monitoring sequence typically consists of an initial optimum (100%) trailed exposure followed by a series of under- and over-exposed trailed spectra and terminates in a final optimum exposure. HD 6300, an early B star, was also observed because it was conveniently located close to the attitude used for the ITF observations. For comparison, each image has been processed with both the current and new LWP ITFs.

The approach taken for this report differs slightly from previous linearity reports. For this report, the linearity errors were determined by ratioing a test exposure to the average of the two 100% exposure level images. Previous reports used only one of the two 100% spectra available in a typical linearity sequence (Oliversen 1983, 1984a and 1984b). This change should help to separate the reproducibility errors from the linearity errors. Each spectral ratio is corrected for the camera head amplifier temperature-induced sensitivity changes (Sonneborn and Garhart, 1983) and is then smoothed with a 5 point median filter and with an 11 point boxcar filter. The resultant ratios are plotted for both the current and new LWP ITFs.

III. ITF2 Versus ITF1 for Optimum Trailed Spectra

A sample plot of an optimum trailed exposure of HD 60753, processed with both the ITF1 and ITF2, is shown in Figure 1. It can be seen that, over the wavelength range from about 2300 to 2700 A, the Flux Number (FN) scale is very similar for images processed with either ITF1 or ITF2. Ratios of optimum spectra processed with ITF2 divided by the same spectra processed with ITF1 are shown in Figures 2a-c. These flux ratios, binned in 25 A bandpasses, are also listed in Table 1. Near the short wavelength end of the LWP, the derived fluxes of an image processed with ITF2 are 3-7% lower than when processed with ITF1. Near the long wavelength end of the LWP, the derived fluxes of an ITF2 image are 7-10% higher than when processed with ITF1 (Figure 2a-c). Therefore, a typical spectral image, when processed with ITF2 and the current

absolute calibration, can be expected to have total errors across the spectrum of about 15%. (Note: ITF2 is not yet used in processing G.O. images and will probably not be used until the new absolute calibration is also available.) The average of six ITF2/ITF1 flux ratios are also listed in Table 1 for each 50 A bin. This average (R_{av}) can be used to correct the absolute calibration of an image which was processed with the new ITF, by:

$$F_{ITF1} = (F_{ITF2} / R_{av}),$$

where F_{ITF2} is the derived flux of an image when processed with ITF2 and the current absolute calibration; R_{av} are the calibration correction factors listed in Table 1, and F_{ITF1} is the absolute flux corrected to the current absolute calibration scale. Strictly speaking this calibration only applies to trailed spectra which are optimally exposed near 2700 A and have low background levels. These correction factors can be used until the new absolute calibration has been derived for the LWP.

As expected, the reproducibility of images processed with the current and new LWP ITFs appear to be similar (Figure 3a-c). Plots of the flux ratios of optimum spectra are shown for September 1982, September 1984 and September 1985. A plot of the ratio of an optimum exposure divided by the average of two optimum exposures is also shown in Figure 4. This gives an example of the noise level typical for the averaged plots and can be used for comparison in the sections which follow.

IV. Non-Optimum Spectra

The flux ratios for several under-exposed spectra processed with ITF1 and ITF2 are shown in Figures 5 and 6a-c. The linearity of underexposed spectra processed with the new ITF is generally improved; however the improvement is not tremendous.

The 20%/100% flux ratio for the images processed with ITF1 appears to be slightly flatter than when processed with ITF2 (Figure 5). However, given that the signal-to-noise level is so low for the 20% image, the differences between the two ITF's may be marginal. Over the short wavelength end of the LWP, flux errors of up to about ±10-15% can be expected for 20% images when processed with either ITF.

The 40%/100% ITF1 flux ratios have a noticeable slope as a function of wavelength. At the short wavelength end, the derived fluxes of a 40% image when processed with ITF1 are too high relative to an optimum exposure by 5-10%, while at the long wavelength end they are too low by 3-5%. The ITF2 image fluxes appear to be slightly 'flatter' or more uniform than the ITF1 images. The ITF2 40%/100% ratios exhibit a similar depression at the long wavelength end of the camera. Near the short wavelength end, the derived fluxes of an 40% image when processed with ITF2 may be too low by at most 5%.

The flux ratios for several over-exposed spectra processed with ITF1 and ITF2 are shown in Figures 7a-c, and 8a,b. There does not appear to be any major differences between the linearity of the 120%/100% or of the 160%/100% ratios between ITF1 or ITF2. Both appear to correct the data equally well. Note that the 160% exposures (LWP 4227 and LWP 6802) contain several extrapolated and saturated pixels in the wavelength region of maximum

sensitivity. For both levels the wavelength ranges of extrapolated pixels are smaller for ITF2 than for ITF1. (eg. LWP 6802; ITF2: 2560-2884 A, ITF1: 2483-2881 A). The highest level of ITF2 is therefore slightly higher than the corresponding level of ITF1. This has the advantage of increasing the range of exposure levels possible for calibrated data with ITF2.

V. High Background Images

Figures 9a-c illustrate linearity errors for spectra obtained with high backgrounds. The image in Figure 9a was produced by exposing the camera to a trailed stellar image and then exposing the camera to empty sky to build up the radiation-induced background level. For the images in Figures 9b and c, a tungsten flood lamp was used to supply the background. The radiation background image has a maximum average continuum level of 172 DN and an average background level of 105 DN. The tungsten flood background images had an average maximum continuum level of 210 DN and 205 DN (LWP 4354 and LWP 4356, respectively) and an average background level of 147 and 105 DN (LWP 4354 and LWP 4356, respectively).

The linearity of high background images when processed with ITF2 appears to be improved compared to the same images when processed with ITF1. The derived fluxes for a spectrum with radiation induced background, when processed with ITF1, are too high relative to an optimum exposure by about 10% near the 2200 to 2500 A region. This enhancement is no longer present for the images when processed with the ITF2. It should be noted that the radiation induced background spectra more closely approximates a spectrum taken during the US2 shift than the tungsten flood lamp exposures (Oliversen, 1984a). Perhaps more striking than the slight linearity improvement is an apparent improvement in the signal-to-noise for all the high background flux ratios. Flux ratio errors of ±15% are common for the ITF1 ratios and are typically reduced to the ±10% level for the ITF2 ratios.

VI. Summary

Overall, the linearity of spectra processed with the ITF2 is improved compared to spectra processed with ITF1. The greatest improvement occurs for the underexposed (40%) and high background images. No significant differences in the linearity of the two ITFs were seen for the overexposed (120% and 160%) spectra. In addition, the new ITF extends to higher DN levels so that less extrapolation is encountered for heavily exposed spectra.

More significant, perhaps, than the improvement in linearity is the improvement in the signal-to-noise of ITF2 compared to the ITF1 images. This is most clearly demonstrated for the high background spectra. A definite improvement in signal-to-noise is seen, especially in the upper portion of flat-field images processed with ITF2 (Scott, 1986). The current ITF was constructed from a set of images using only one image per ITF level. One of the major enhancements of the new ITF is the use of at least 4 images per ITF level. This is probably the major reason for the improvement in the signal-to-noise.

References

Oliversen, N. A. 1983, NASA IUE Newsletter, No. 23, p. 31.

Oliversen, N. A. 1984a, NASA IUE Newsletter, No. 24, p. 27.

Oliversen, N. A. 1984b, NASA IUE Newsletter, No. 24, p. 50.

Scott, H. 1986, Report presented at the June IUE Three-Agency Committee Meeting.

Sonneborn, G. and Garhart, M. 1983, NASA IUE Newsletter, No. 23, p. 23.

Table 1

Binned Flux Ratios for 100%(ITF2) / 100%(ITF1)

Central Wavelength	Day 263, 1982 LWP 1667*	LWP 1674	Day 258, 1984 LWP 4224*	LWP 4232	Day 268, 1985 LWP 6799*	LWP 6804	R_{av}
2100	0.933	0.971	0.961	1.004	0.989	0.985	0.974 ± .025
2150	0.978	1.018	1.005	1.036	1.043	1.016	1.016 ± .023
2200	0.994	0.996	0.998	1.002	0.997	0.986	0.994 ± .007
2250	0.994	0.999	0.985	0.997	0.983	0.986	0.991 ± .007
2300	0.998	1.029	1.012	1.018	1.013	1.027	1.016 ± .011
2350	1.002	1.016	1.007	1.026	1.036	1.045	1.022 ± .017
2400	1.014	1.024	1.017	1.027	1.026	1.039	1.025 ± .009
2450	1.002	1.009	1.006	1.017	1.021	1.022	1.013 ± .008
2500	1.002	1.010	1.006	1.010	1.018	1.021	1.011 ± .007
2550	1.008	1.010	1.013	1.014	1.018	1.020	1.014 ± .005
2600	1.008	1.017	1.013	1.019	1.028	1.026	1.018 ± .008
2650	1.016	1.018	1.020	1.021	1.030	1.033	1.023 ± .007
2700	1.036	1.042	1.038	1.038	1.038	1.039	1.039 ± .002
2750	1.036	1.038	1.036	1.039	1.037	1.041	1.037 ± .002
2800	1.039	1.037	1.038	1.039	1.042	1.043	1.040 ± .002
2850	1.047	1.042	1.045	1.045	1.045	1.046	1.045 ± .002
2900	1.042	1.041	1.042	1.041	1.042	1.041	1.042 ± .001
2950	1.048	1.046	1.049	1.048	1.049	1.049	1.048 ± .001
3000	1.065	1.056	1.060	1.060	1.059	1.063	1.061 ± .003
3050	1.076	1.068	1.067	1.070	1.077	1.076	1.072 ± .005
3100	1.089	1.080	1.083	1.084	1.094	1.092	1.087 ± .006

* see Figures 2a-c

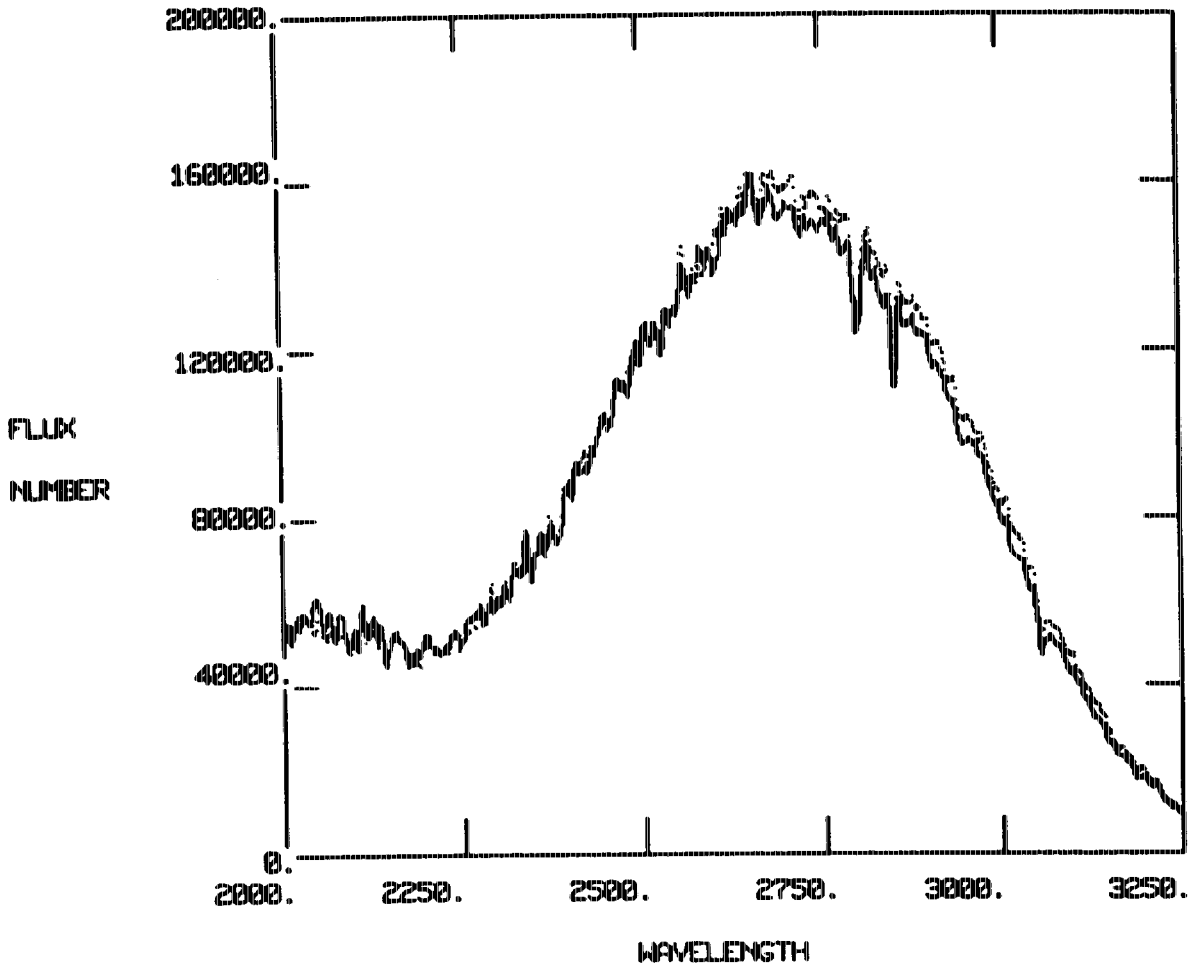


Figure 1 HD 60753 100% TRAILED SPECTRA - LWP 4224
DAY 270, 1984
LINE = ITF1 DOTS = ITF2

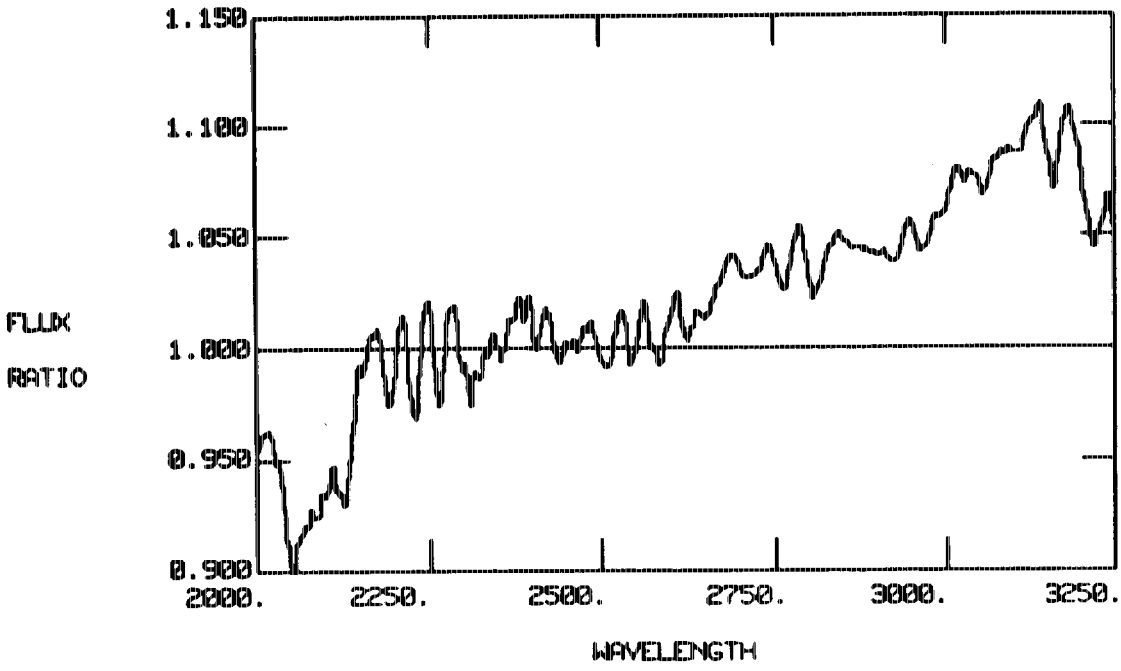


Figure 2a HD 60753 100% (ITF2) 100% (ITF1)
LWP 1667
DAY 263, 1982

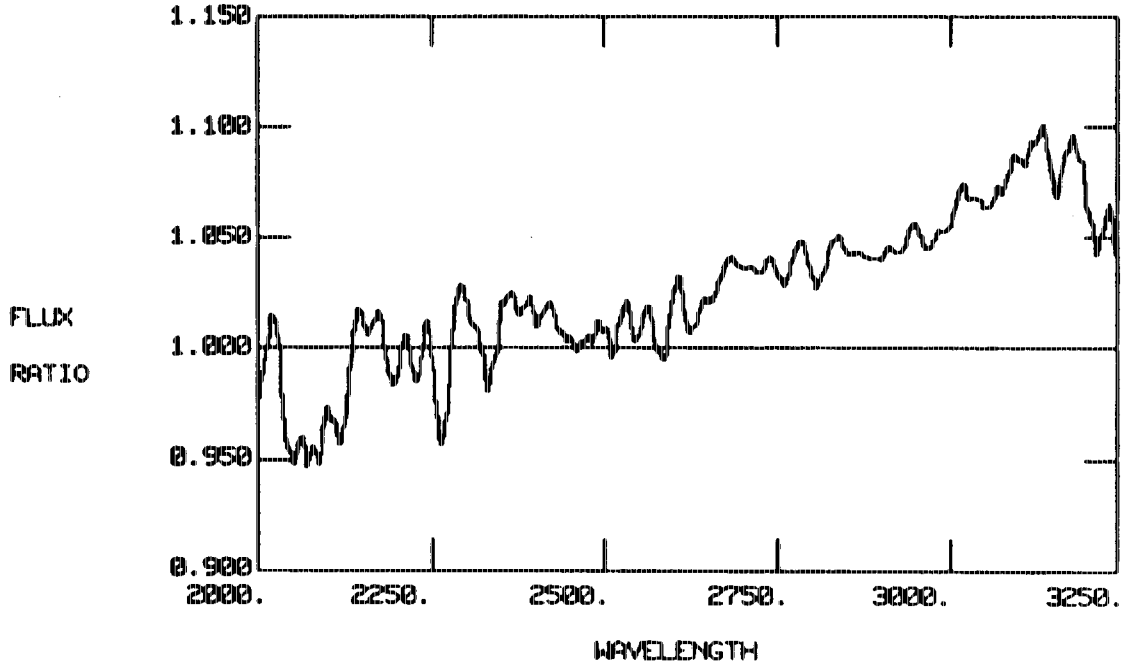


Figure 2b HD 60753 100% (ITF2) / 100% (ITF1)
LWP 4224
DAY 258, 1984

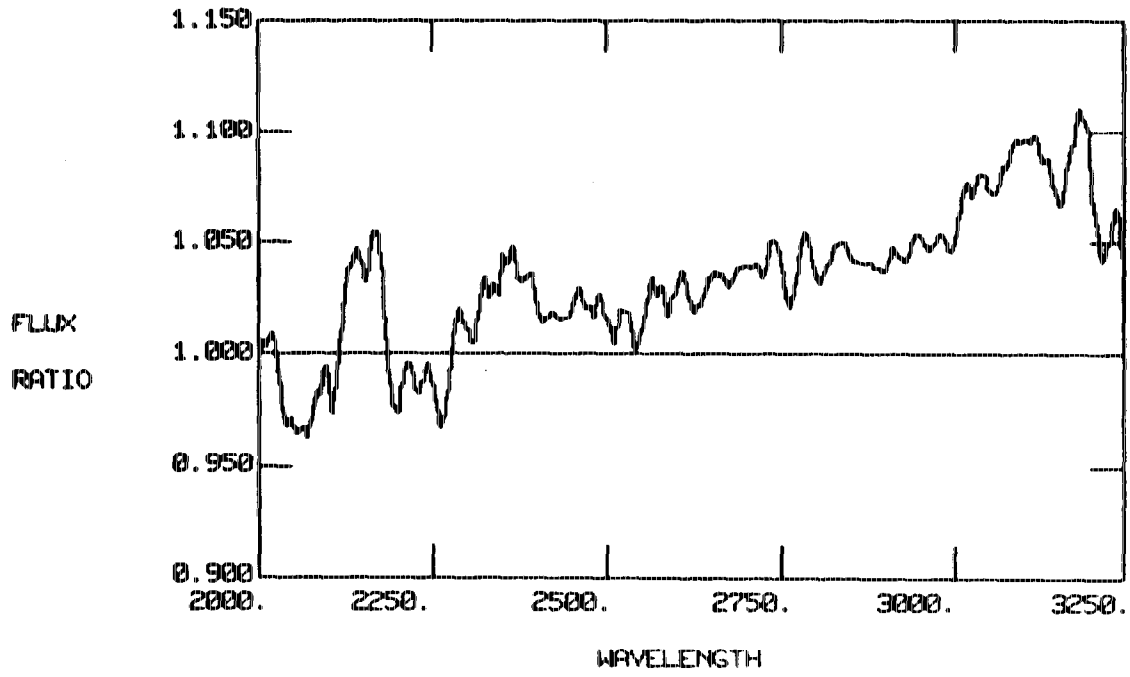
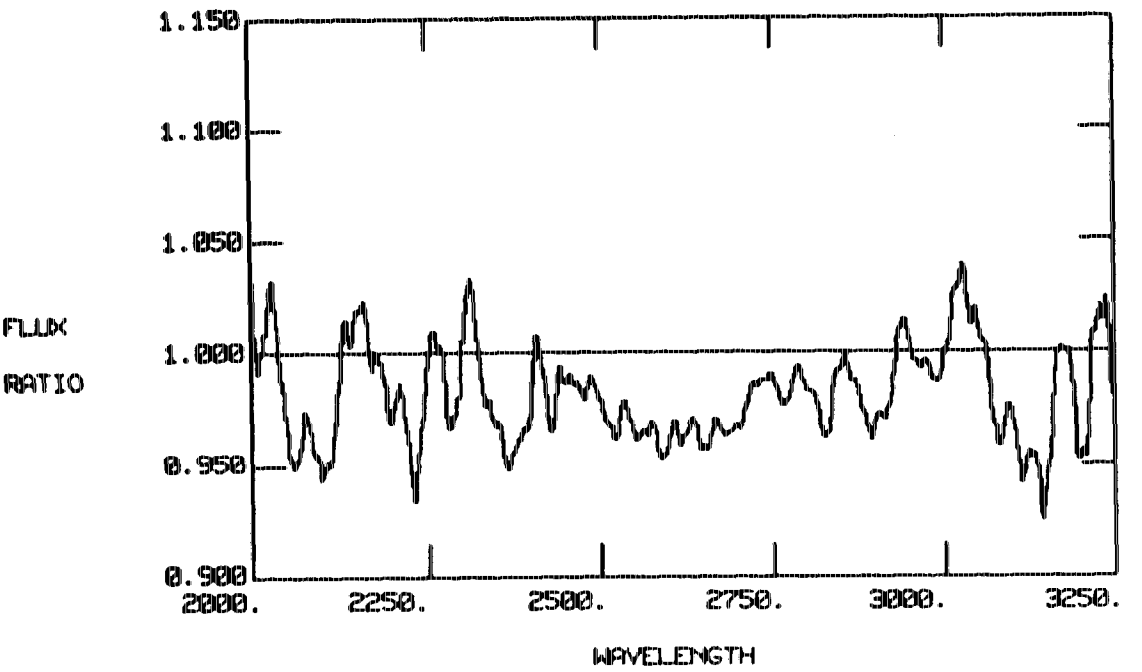


Figure 2c HD 60753 100% (ITF2) / 100% (ITF1)
LWP 6799
DAY 268, 1985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1.050
1.000
0.950
0.900
FLUX
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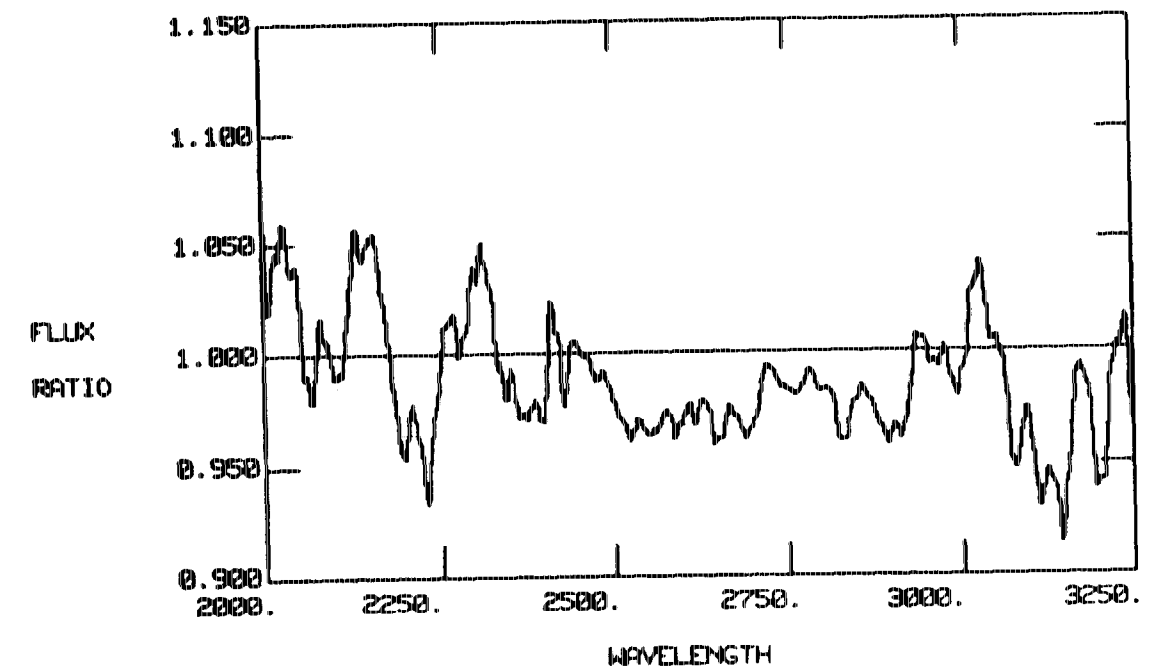
2250.
2500.
2750.
3000.
3250.
WAVELENGTH
HD 60753
REPRODUCIBILITY 100%/100%
LWP 1667 / LWP 1674
DAY 263, 1982
ITF2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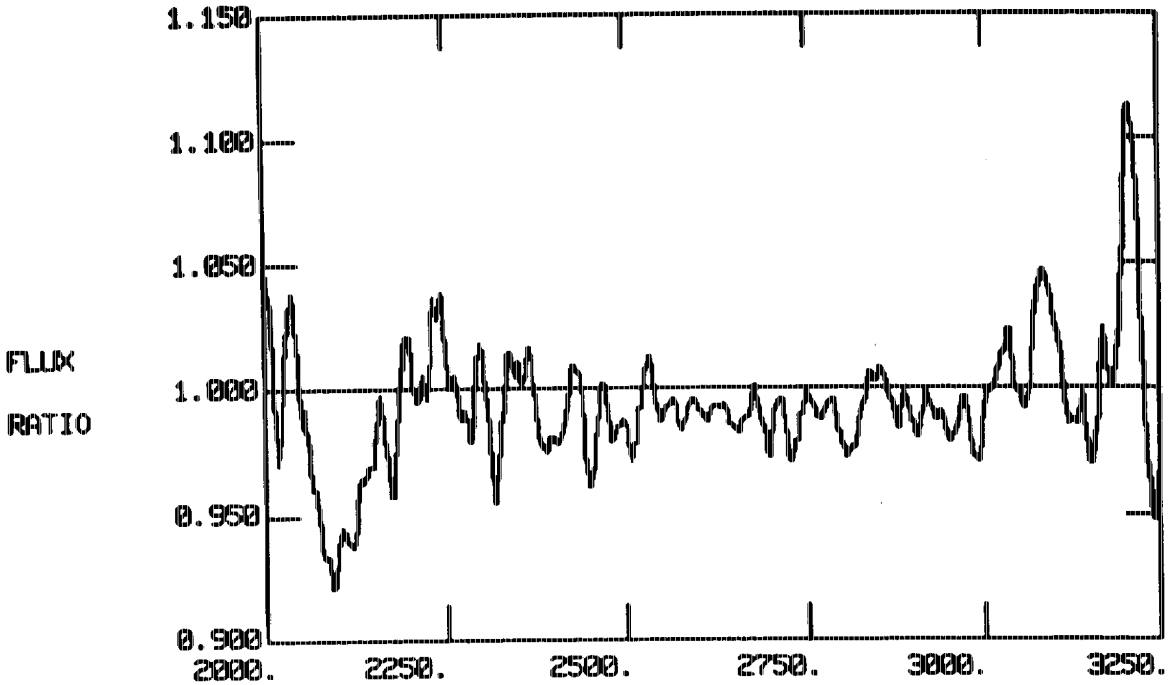
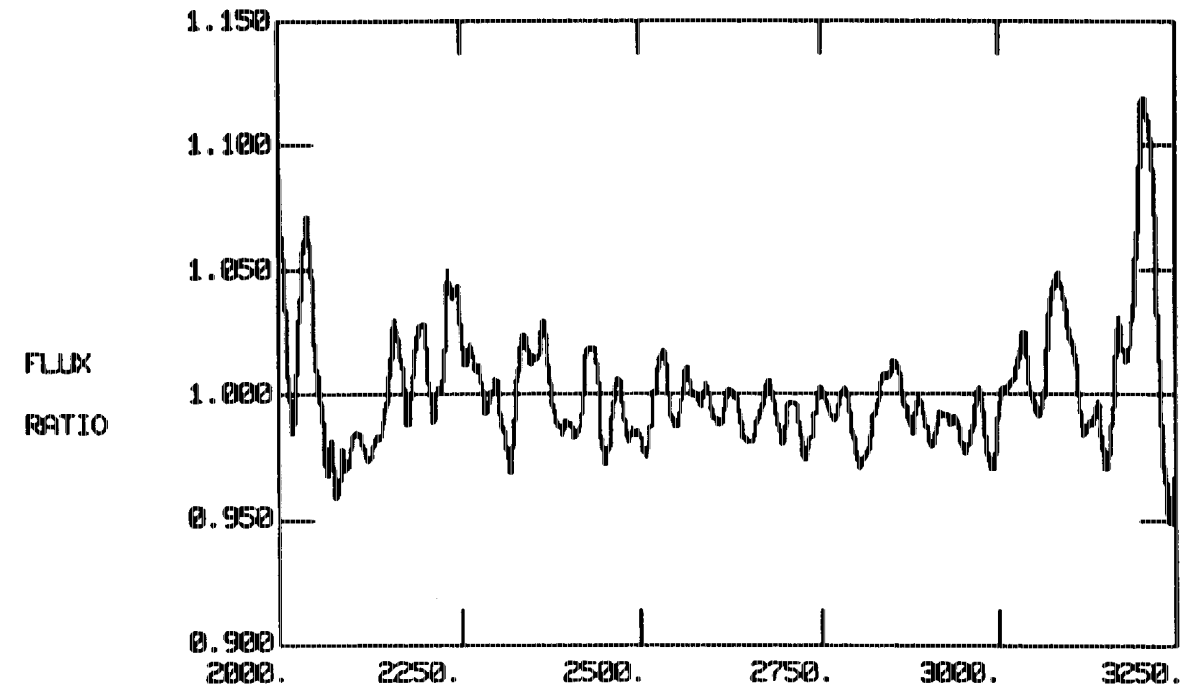
WAVELENGTH
HD 60753
REPRODUCIBILITY 100%/100%
LWP 1667 / LWP 1674
DAY 263, 1982
ITF1

Figure 3a



HD 60753 100%/100%
LWP 4224 / LWP 4232
DAY 258, 1984 ITF2



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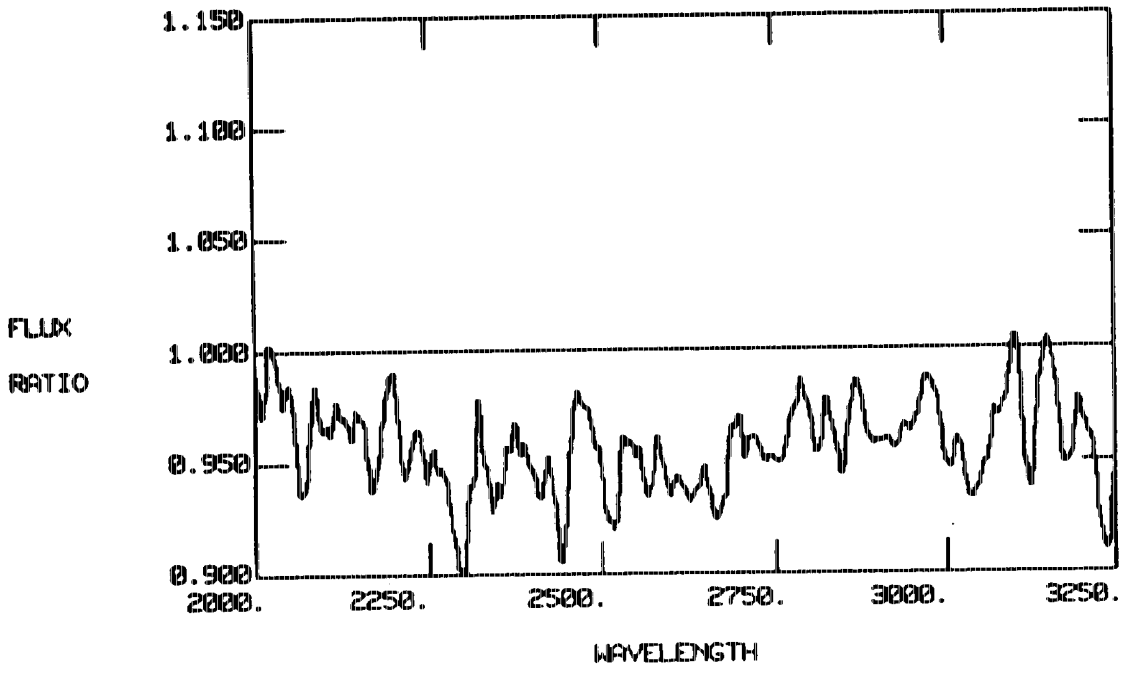
LWP 4224 / LWP 4232
DAY 258, 1984 ITF1

Figure 3b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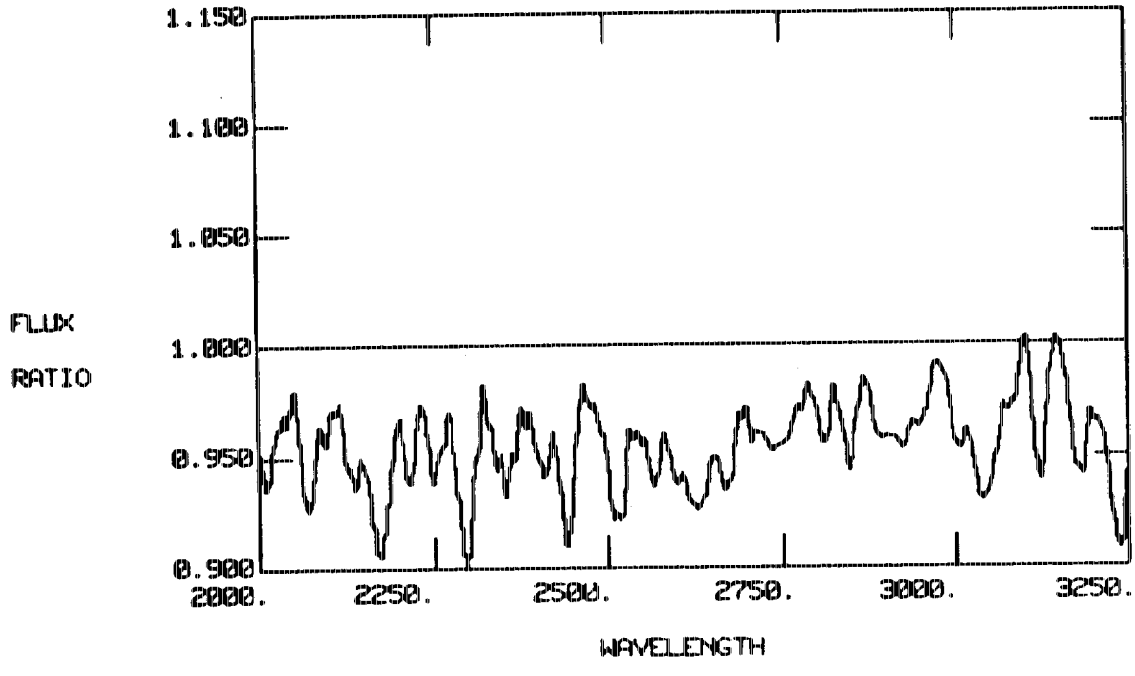
WAVELENGTH
HD 60753 100% / 100% REPRODUCIBILITY
LWP 6799 / LWP 6804
DAY 268, 1985 ITF2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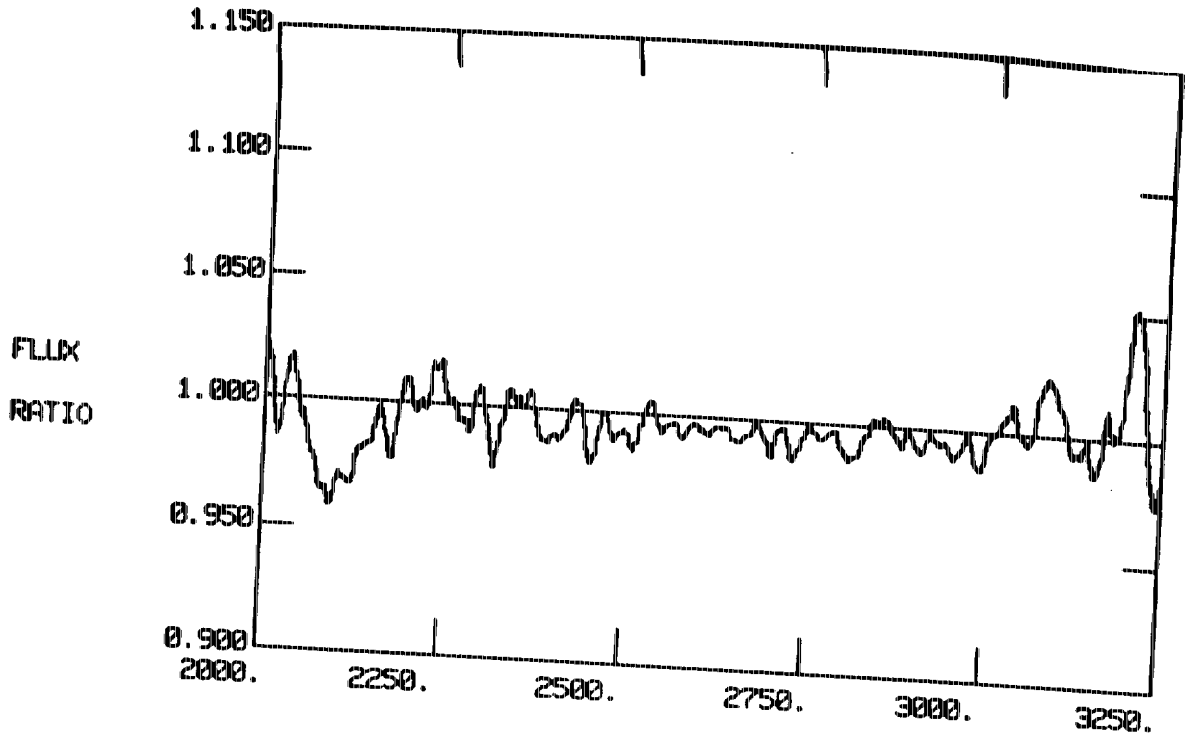
WAVELENGTH
HD 60753 100% / 100% REPRODUCIBILITY
LWP 6799 / LWP 6804
DAY 268, 1985 ITF1

Figure 3c



HD 60753 100%/100% REPRODUCIBILITY
LWP 4224 / ((LWP 4224 + LWP 4232)/2
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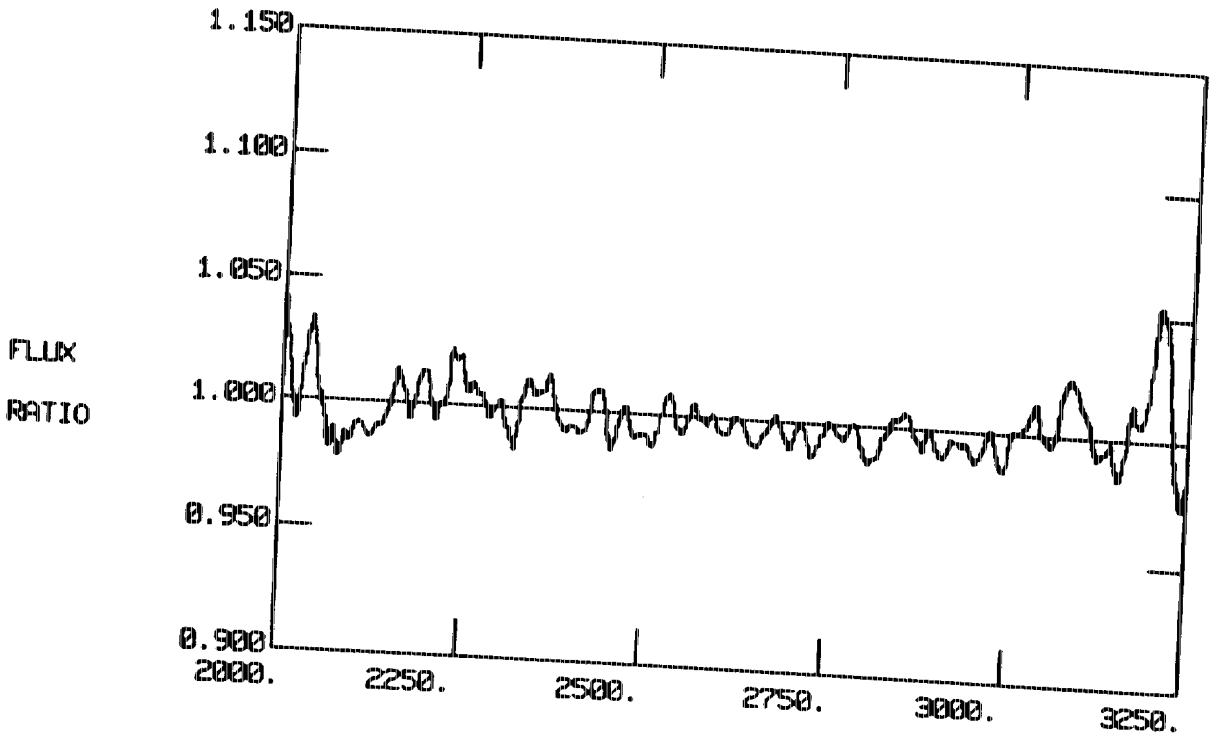

HD 60753 100%/100% REPRODUCIBILITY
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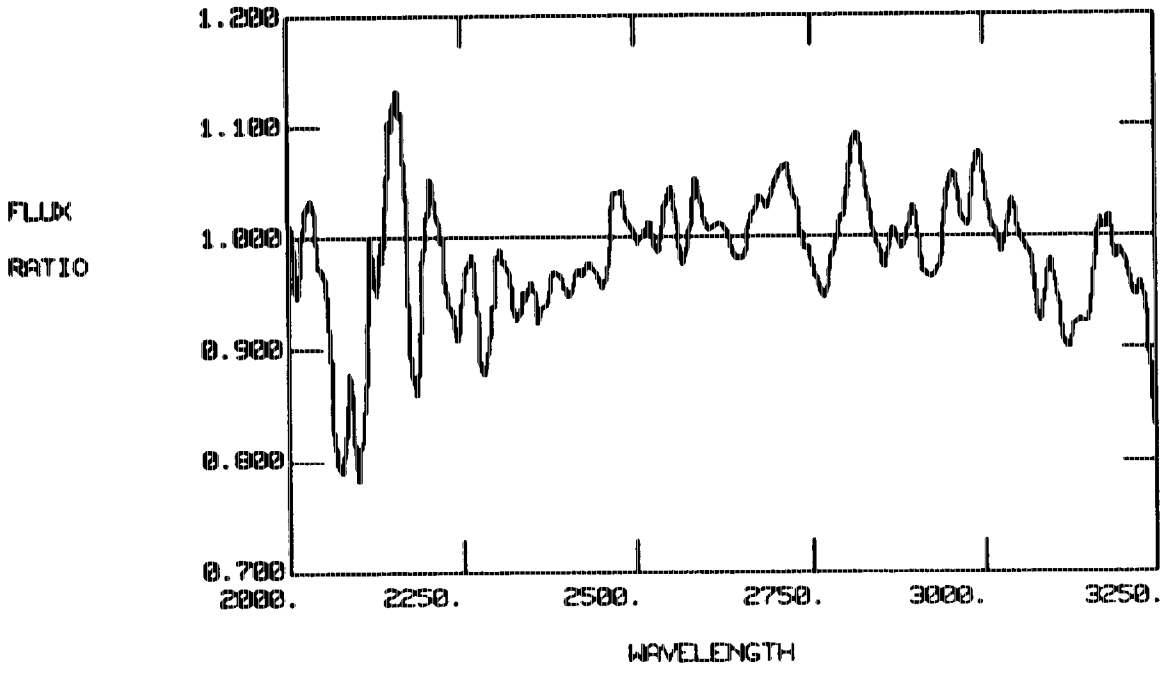
DAY 258, 1984 ITF1

Figure 4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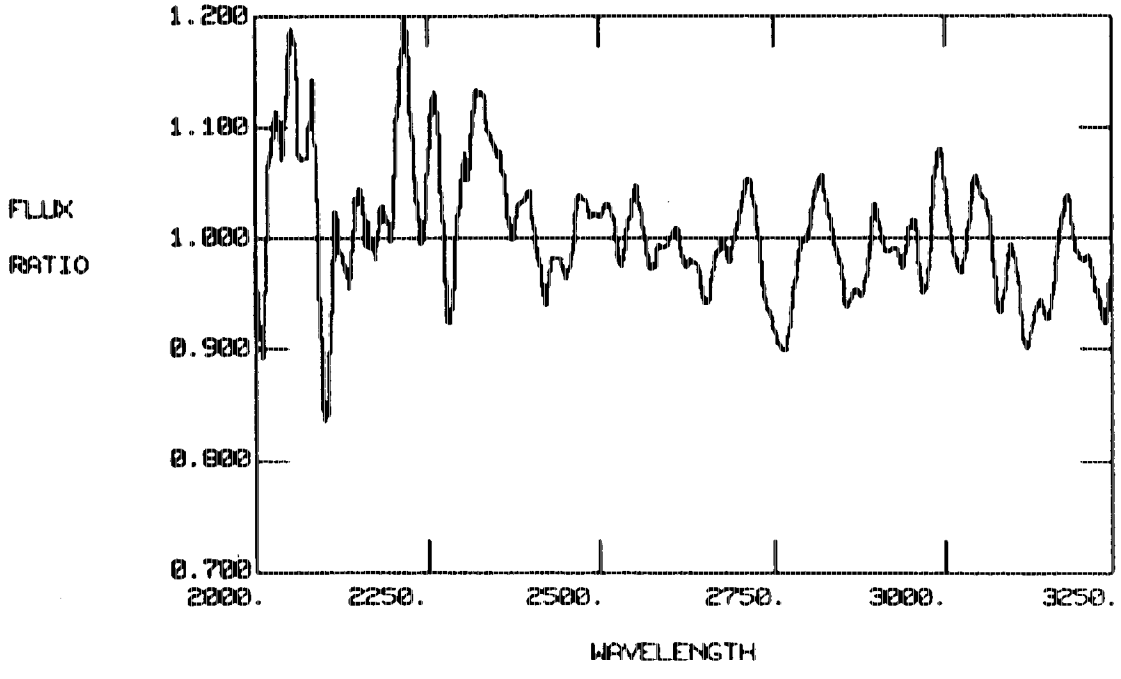
20% / 100%
LWP 1672 / ((LWP 1667 + LWP 1674)/2)
DAY 263, 1982
ITF2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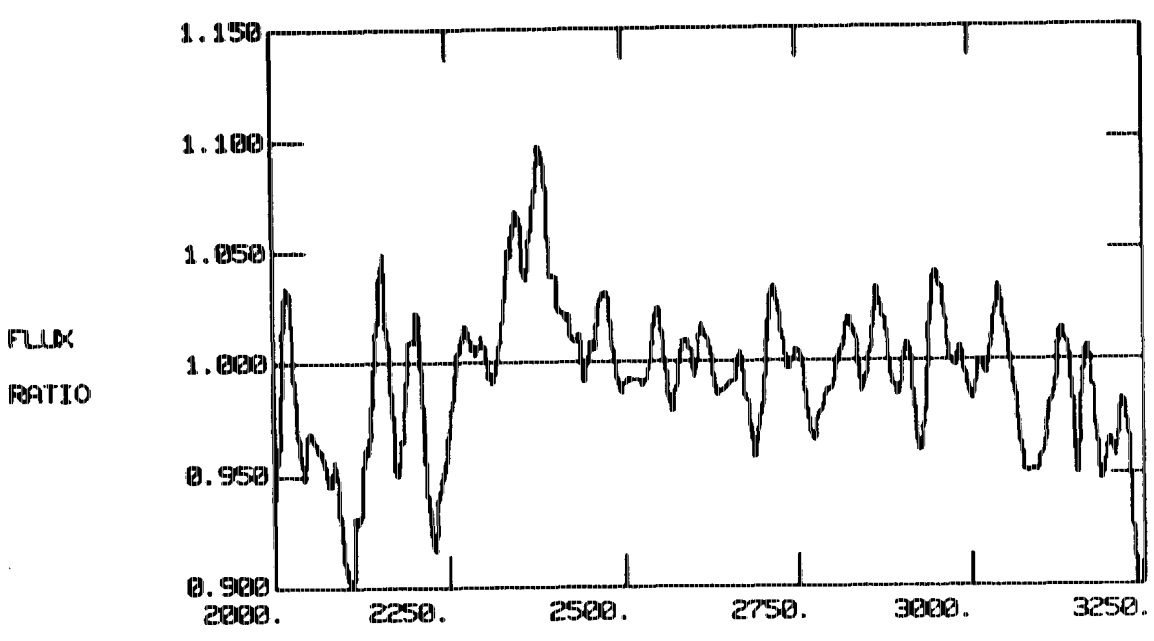
HD 60753
20% / 100%
LWP 1672 / ((LWP 1667 + LWP 1674)/2)
DAY 263, 1982
ITF1

Figure 5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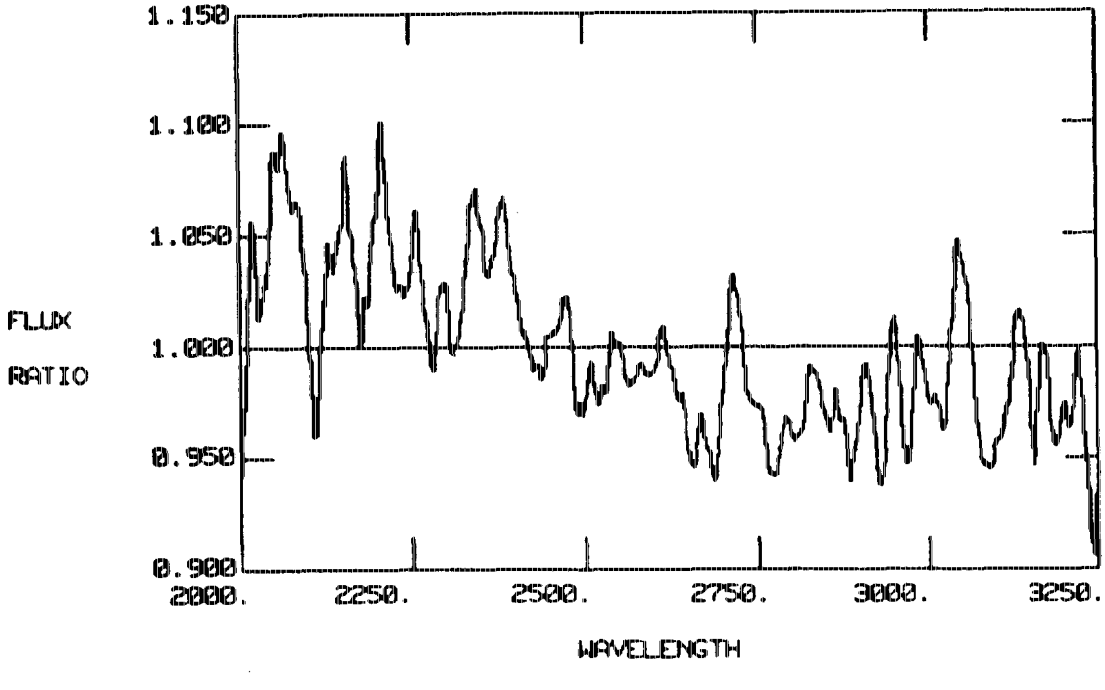
40% / 100%
LWP 1670 / ((LWP 1667 + LWP 1674)/2)
DAY 263, 1982
ITF2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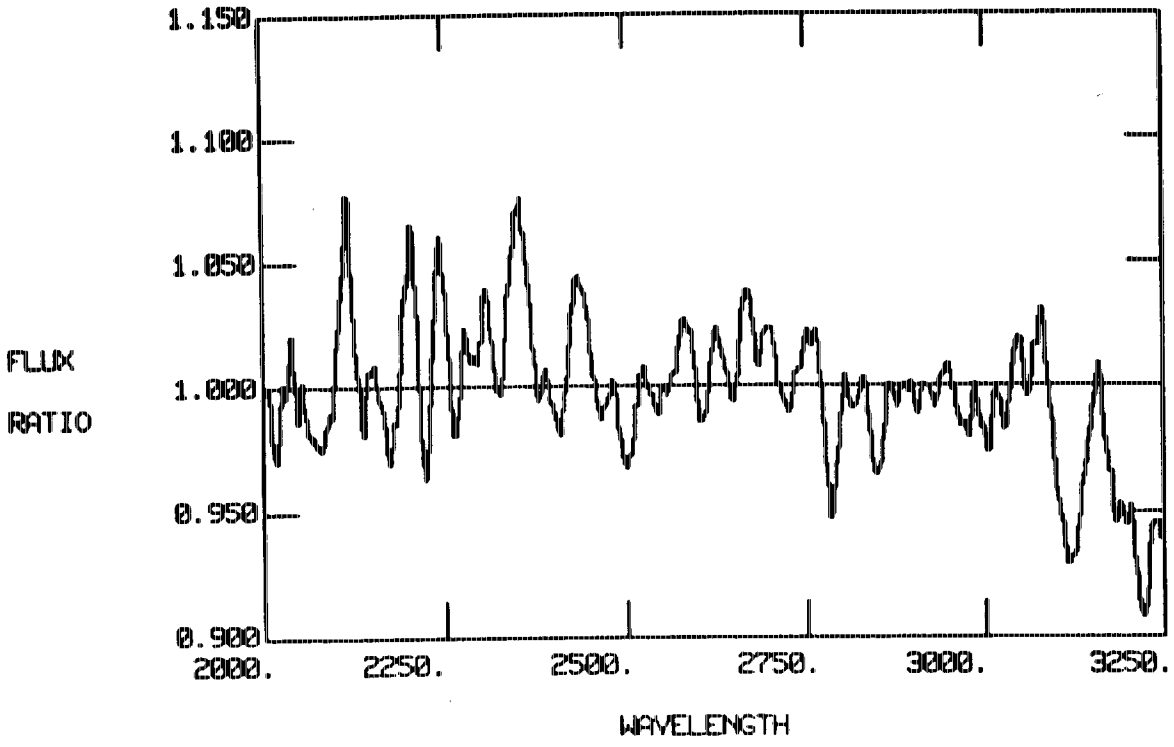
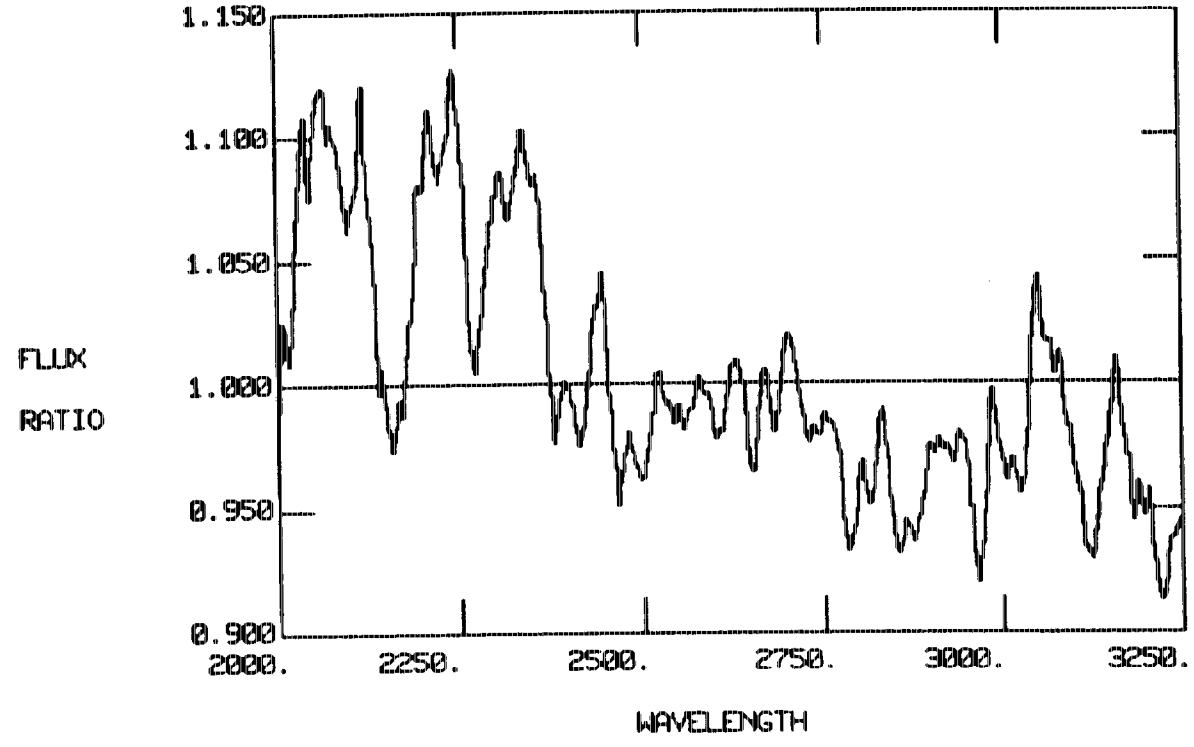
HD 60753
40%/100%
LWP 1670 / ((LWP 1667 + LWP 1674)/2)
DAY 263, 1982
ITF1

Figure 6a



HD 60753 40%/100%
LWP 4225 / ((LWP 4224 + LWP 4232)/2
DAY 258, 1984 ITF2



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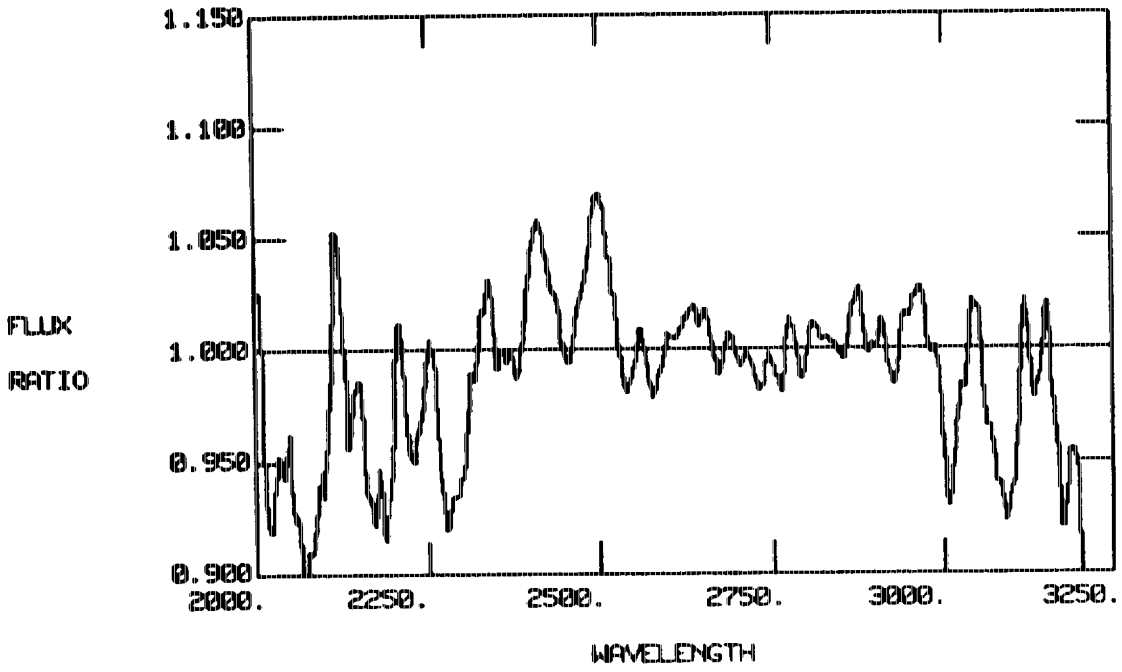
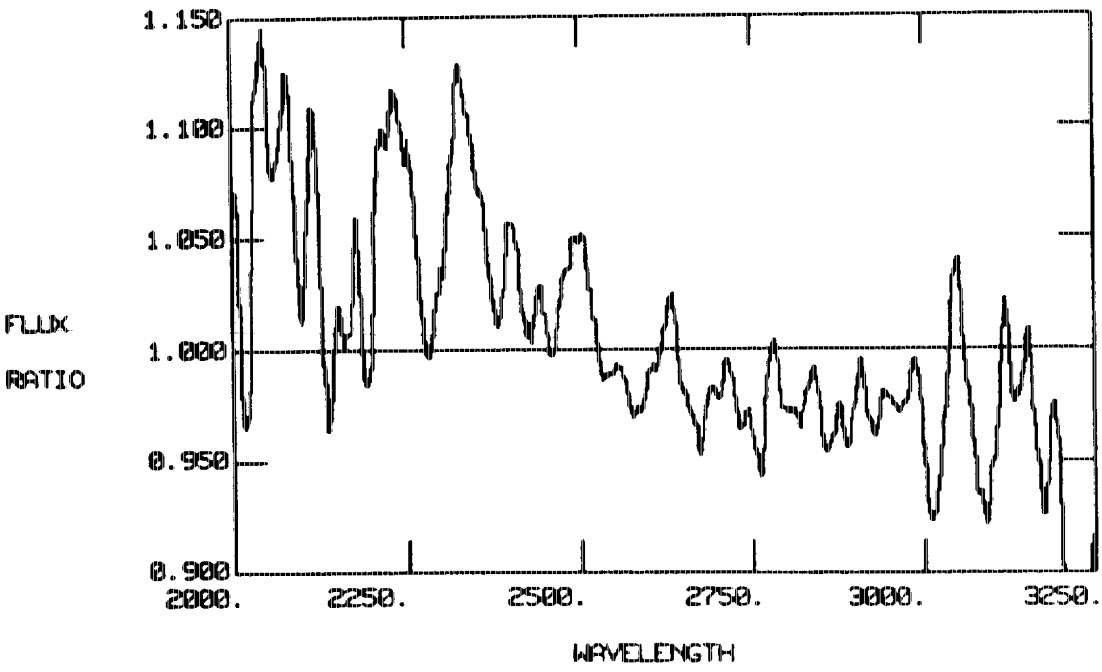
DAY 258, 1984 ITF1

Figure 6b



HD 60753 40% / 100%
LWP 6800 / ((LWP 6799 + LWP 6804)/2)
DAY 268, 1985 ITF2



HD 60753 40% / 100%
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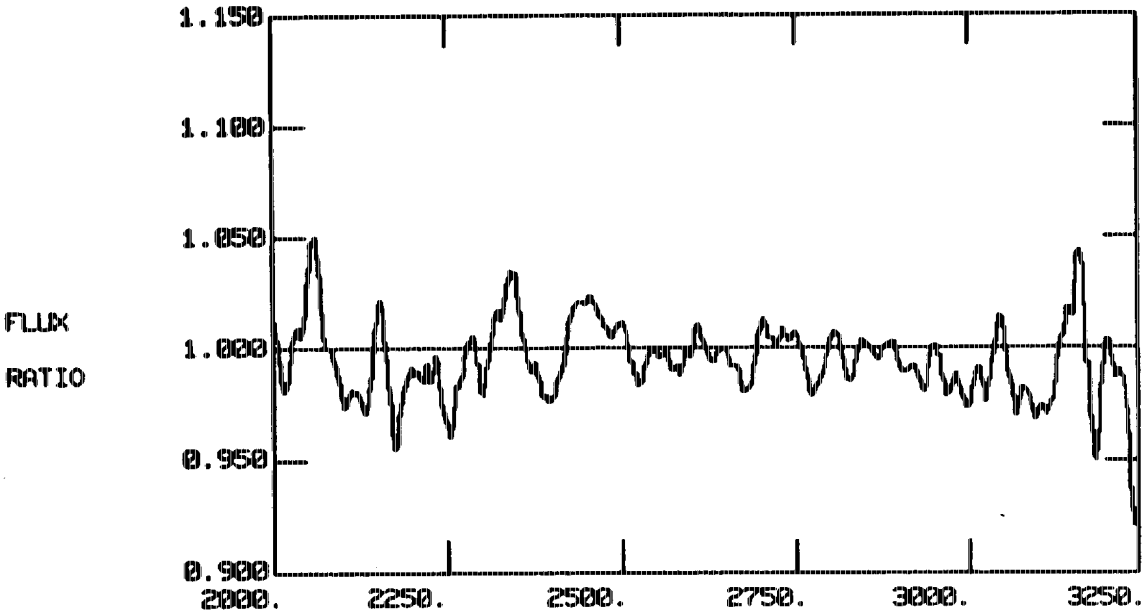
DAY 268, 1985 ITF1

Figure 6c



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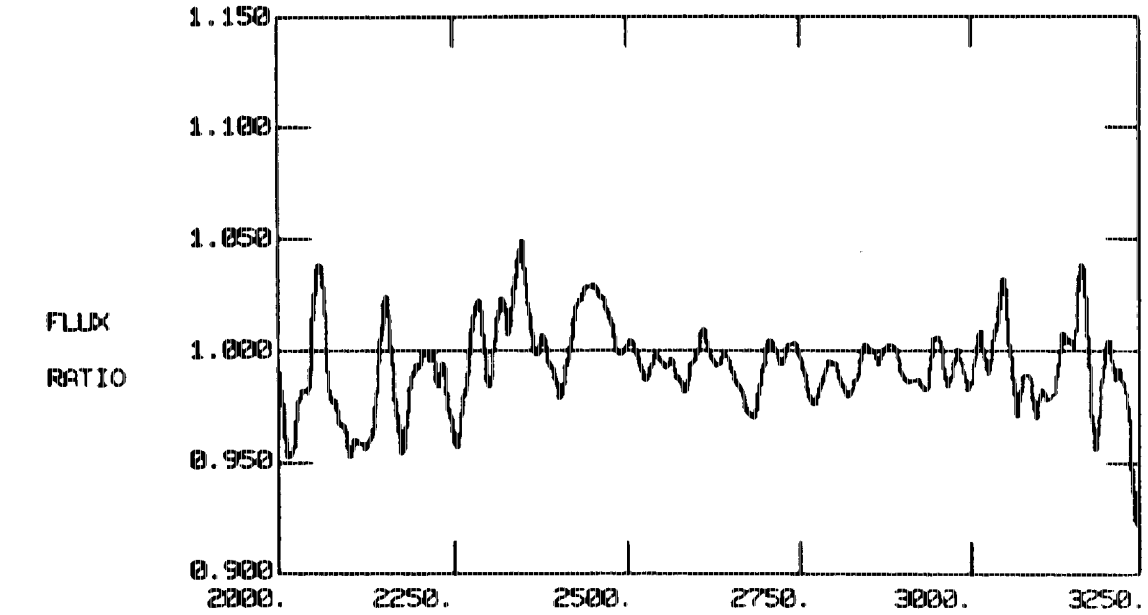
DAY 263, 1982 ITF2



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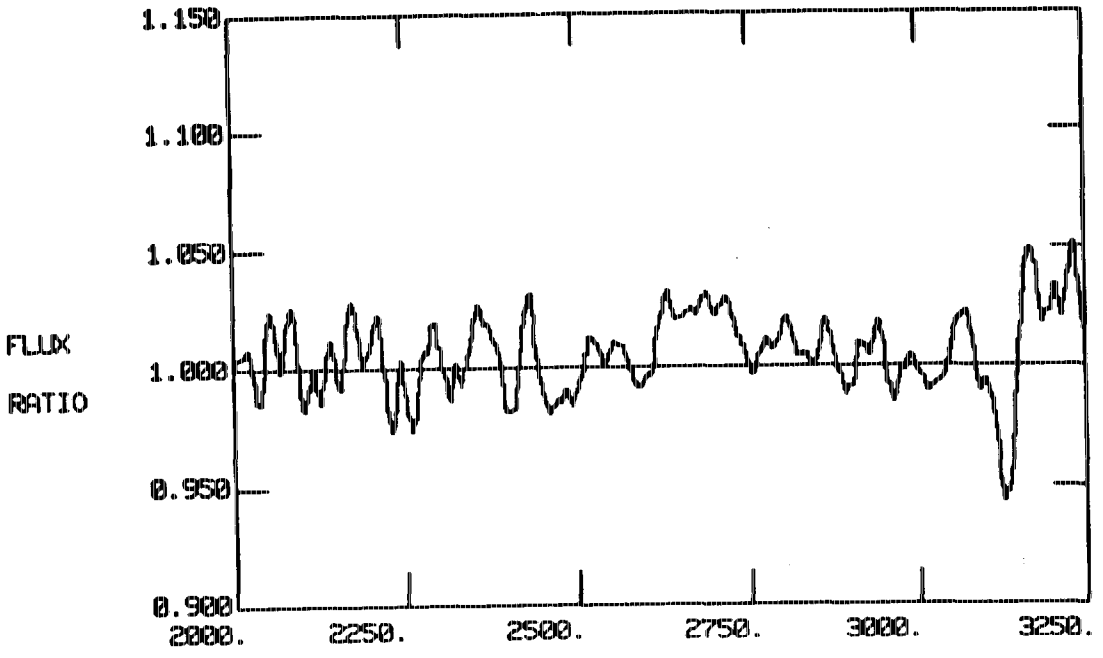
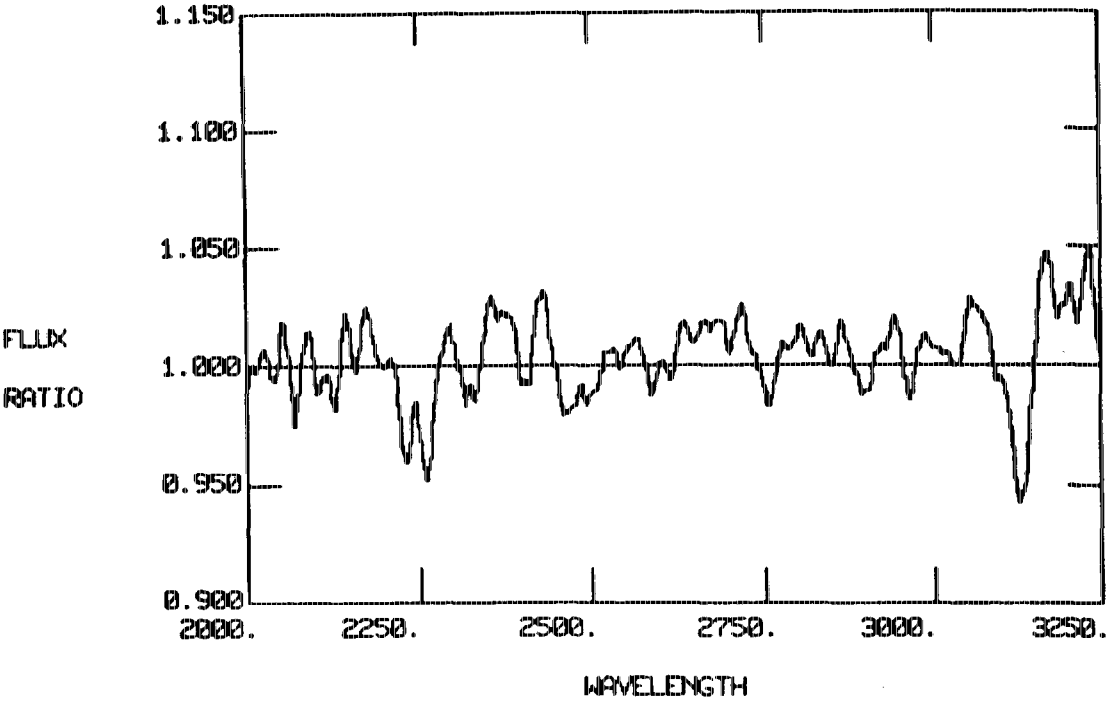
DAY 263, 1982 ITF1

Figure 7a

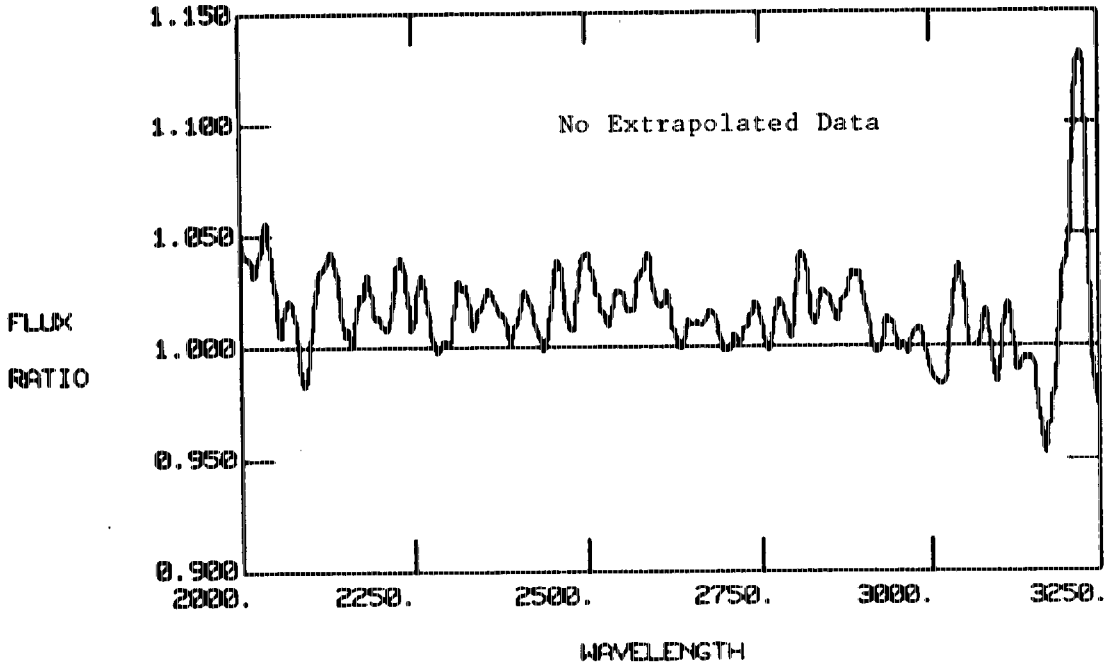


HD 60753 120%/100%
LWP 4226 / ((LWP 4224 + LWP 4232)/2)
DAY 258, 1984 ITF2



HD 60753 120%/100%
LWP 4226 / ((LWP 4224 + LWP 4232)/2)
DAY 258, 1984 ITF1

Figure 7b



HD 60753 120%/100%
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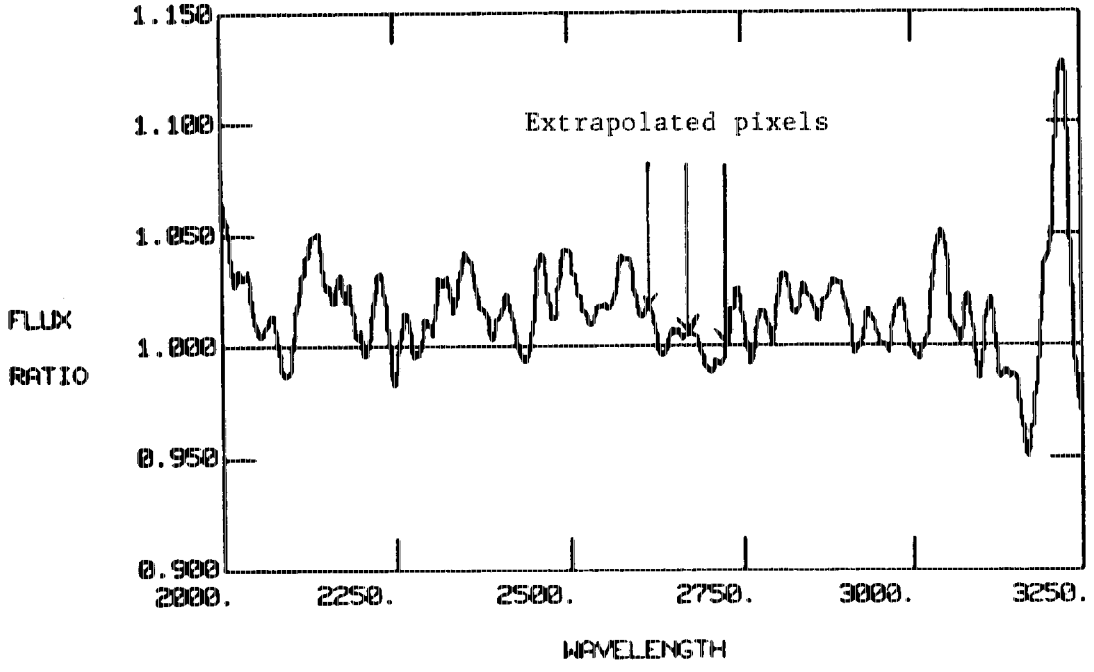
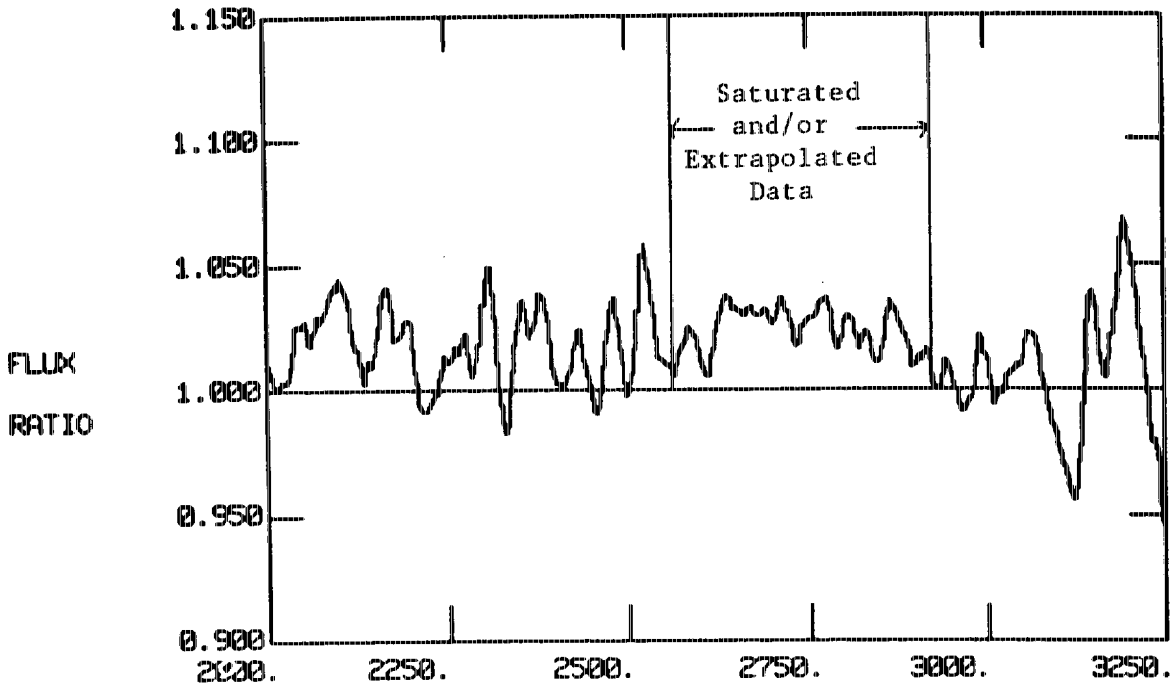
DAY 268, 1985 ITF2

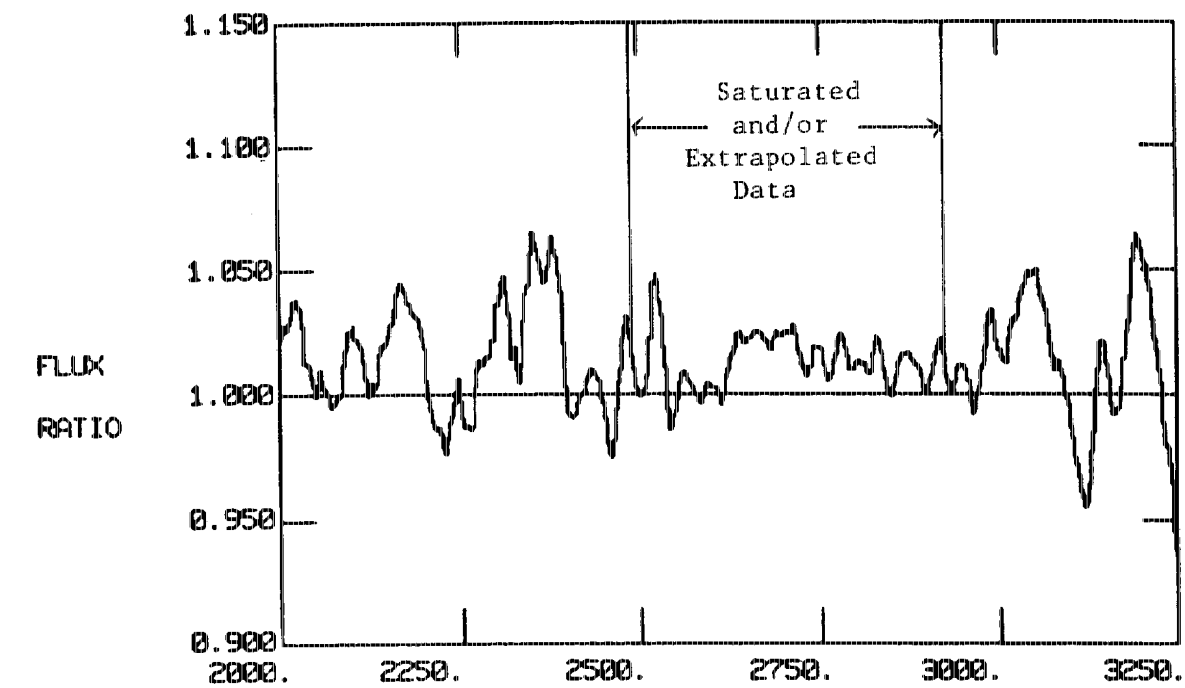


HD 60753 120% / 100%
LWP 6801 / ((LWP 6799 + LWP 6804)/2)
DAY 268, 1985 ITF1

Figure 7c

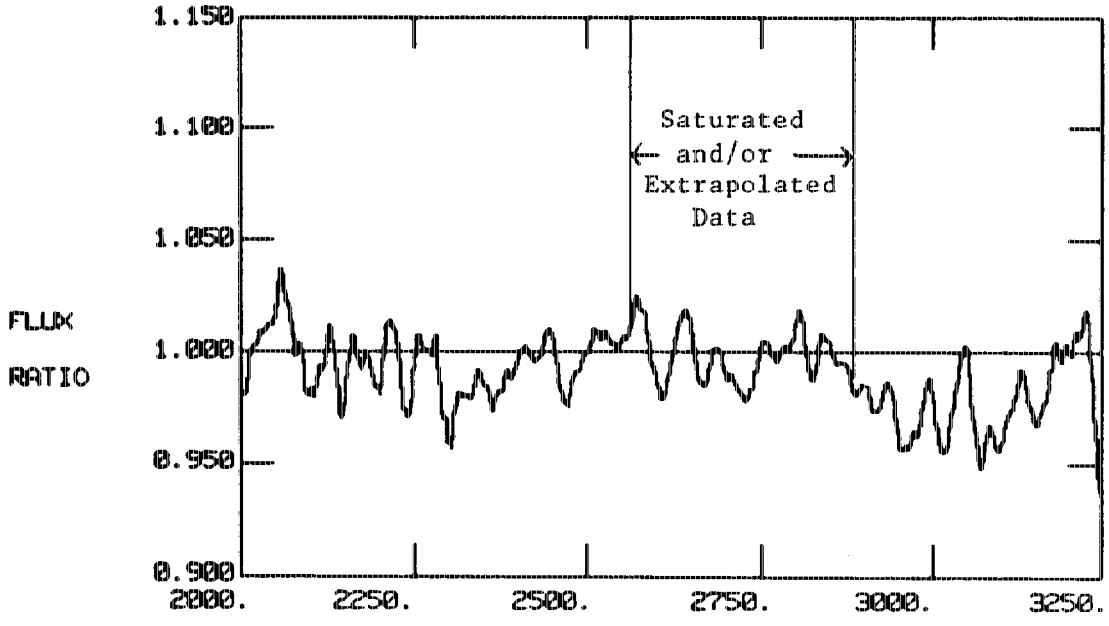


HD 60753 160%/100%
LWP 4227 / (LWP 4224 + LWP 4232))/2
DAY 258, 1984 ITF2

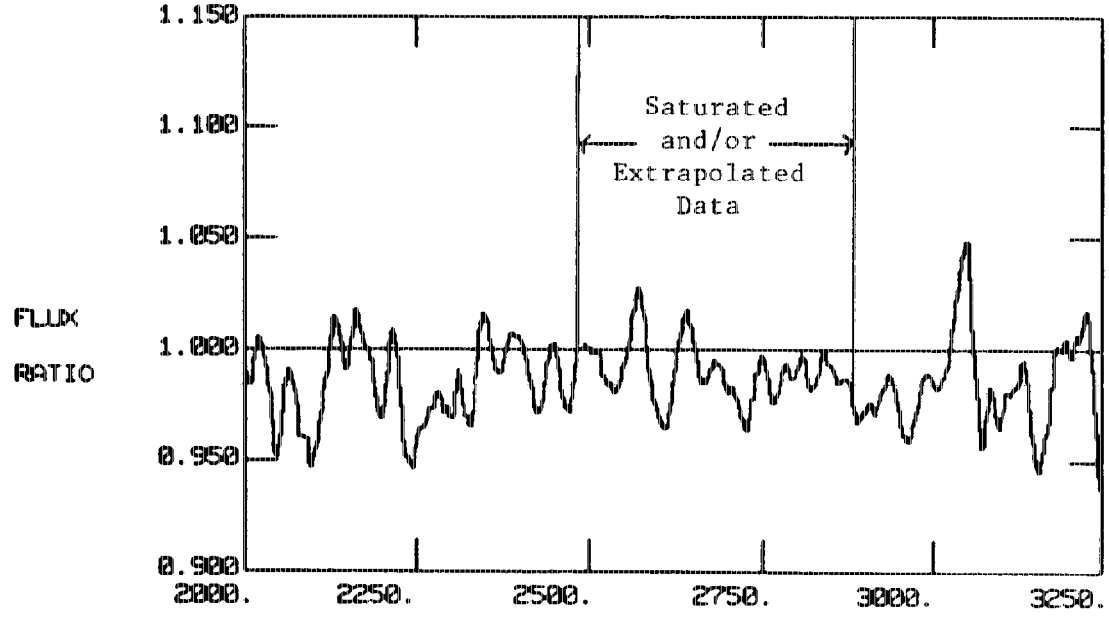


HD 60753 160%/100% TRAILED
LWP 4227 / ((LWP 4224 + LWP 4232)/2
DAY 258, 1984 ITF1

Figure 8a

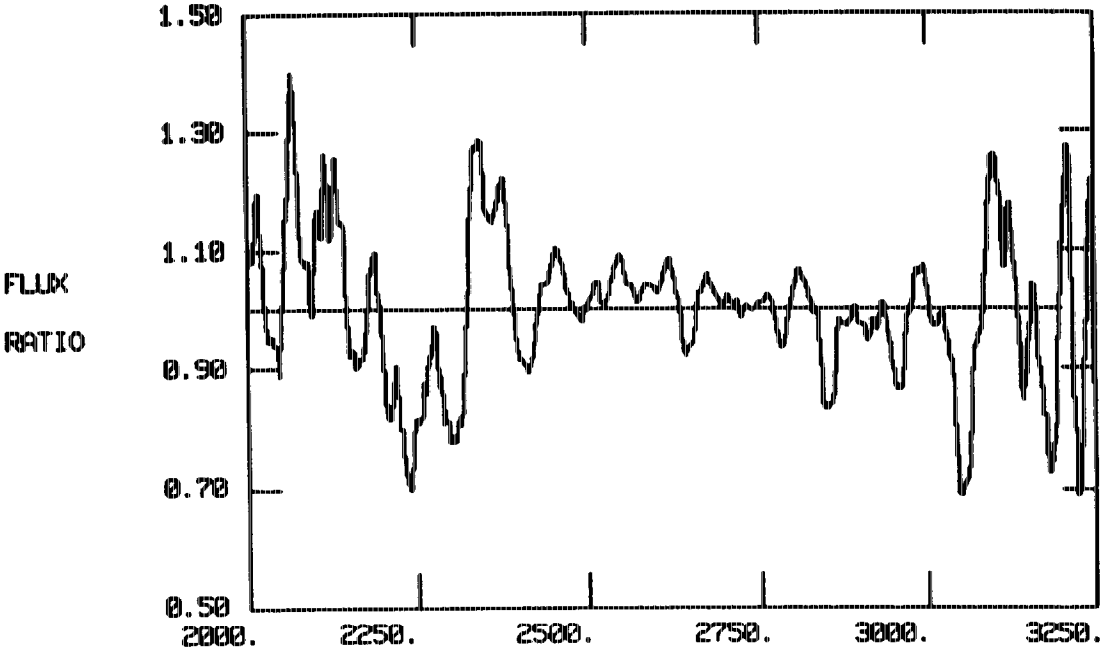


HD 60753 160% / 100%
LWP 6802 / ((LWP 6799 + LWP 6804)/2)
DAY 268, 1985 ITF2

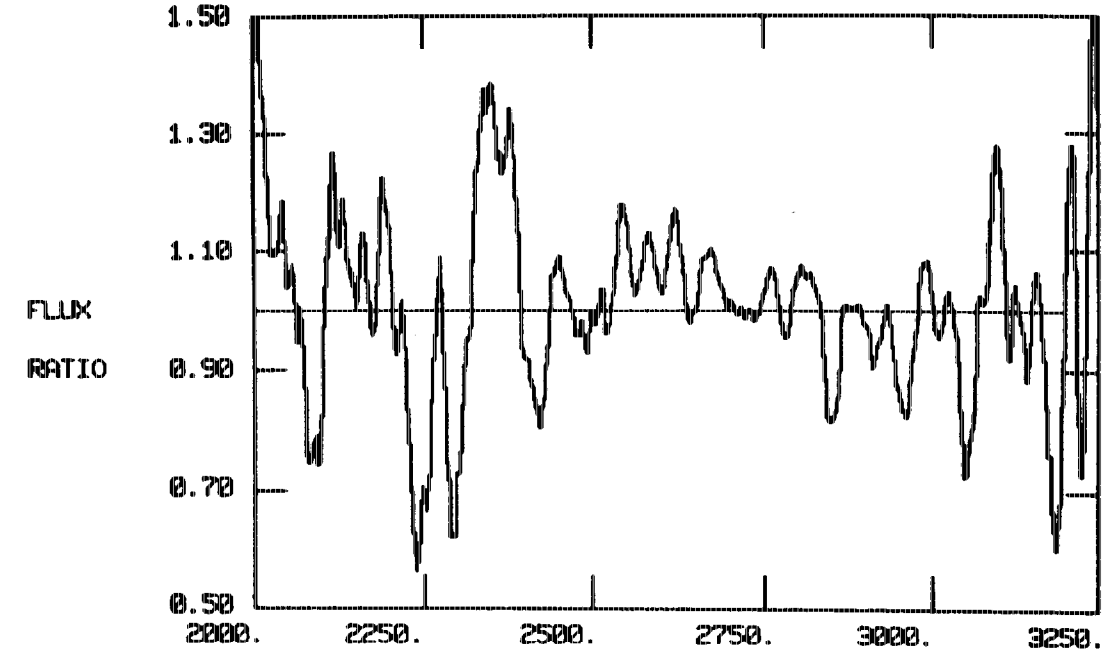


HD 60753 160% / 100%
LWP 6802 / ((LWP 6799 + LWP 6804)/2)
DAY 268, 1985 ITF1

Figure 8b

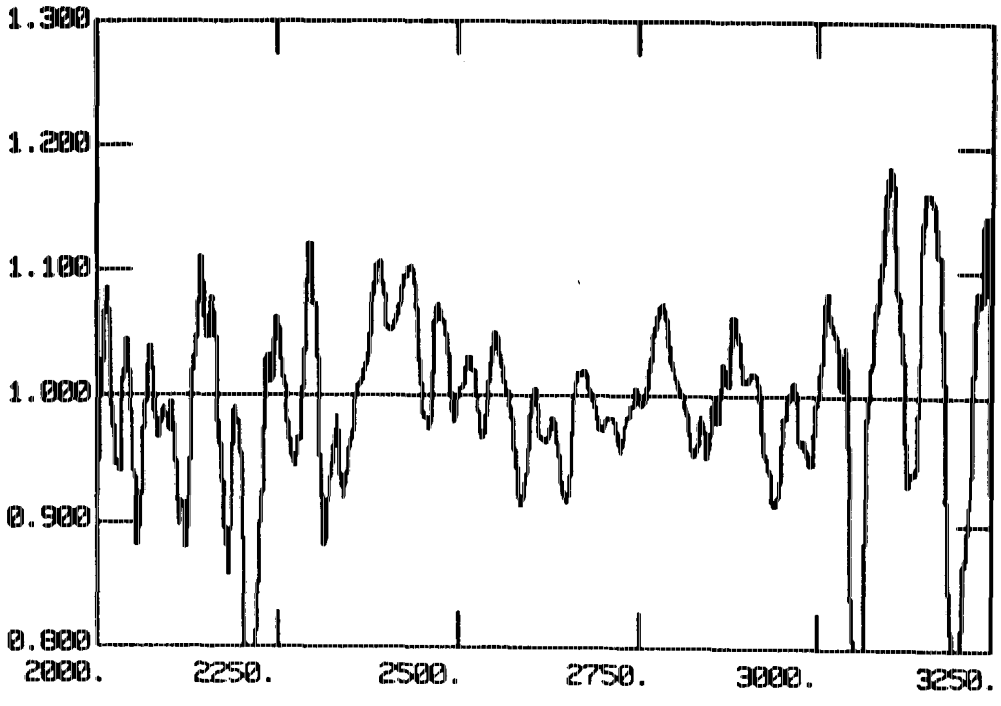


HD 6300 (30% + TFLOOD BACKGROUND) / 100%
LWP 4354 / ((4352 + LWP 4357)/2
DAY 270 1984 ITF2

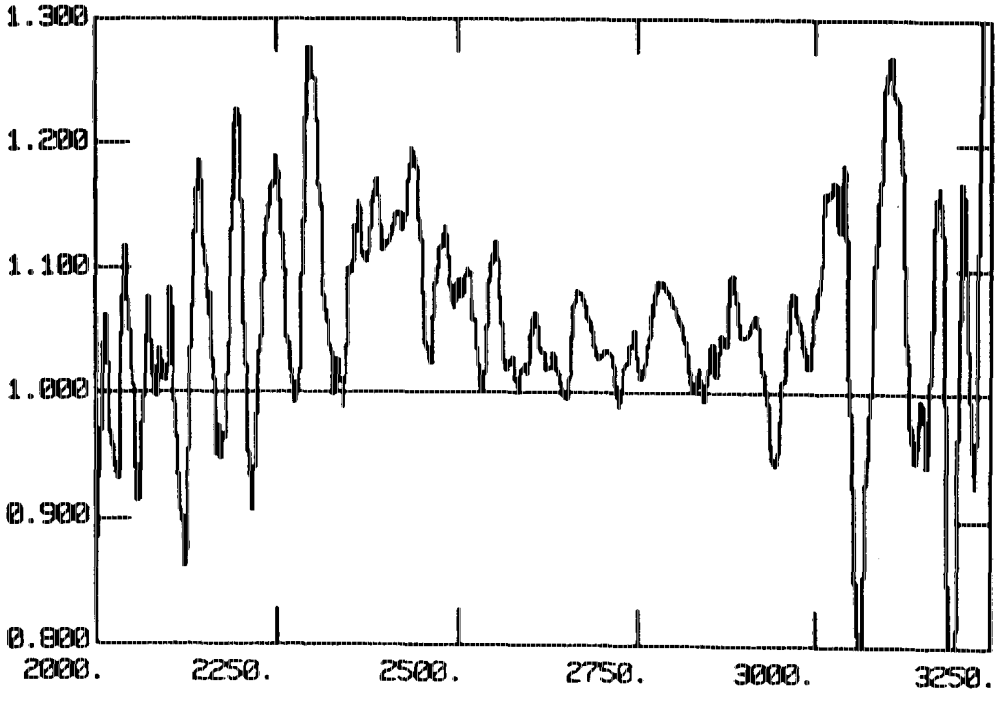


HD 6300 (30% + TFLOOD BACKGROUND)/ 100%
LWP 4354 / ((LWP 4352 + LWP 4357)/2
DAY 270 1984 ITF1

Figure 9a

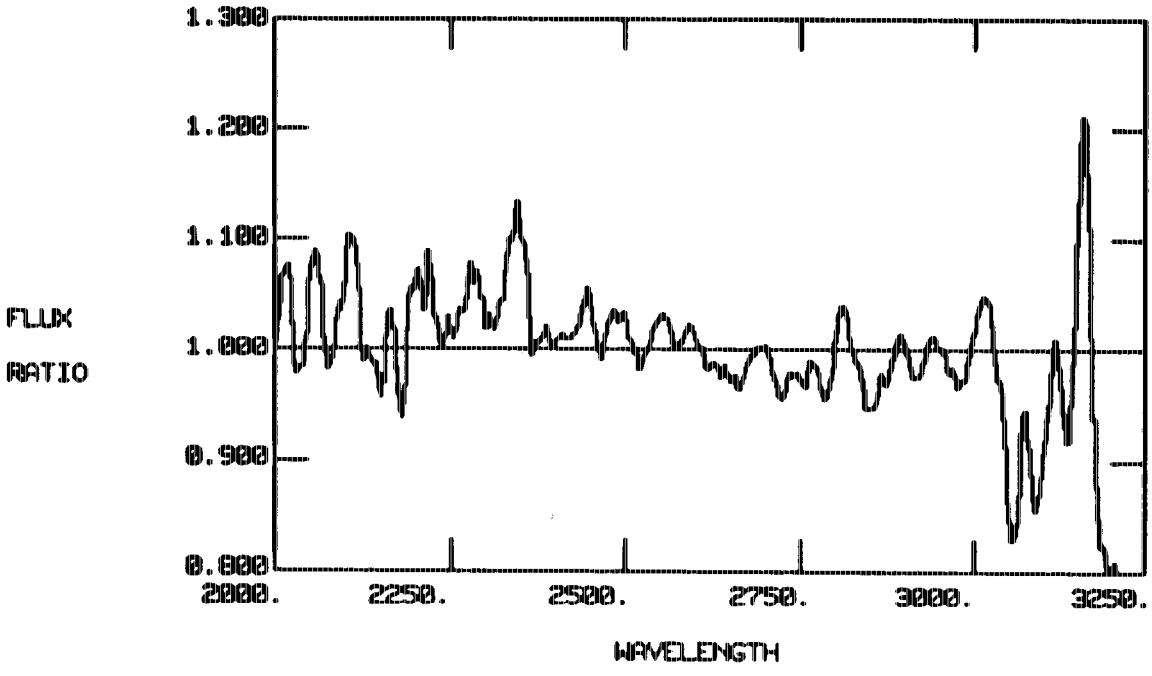


HD 6300 (30% + RADIATION BACKGROUND) / 100%
LWP 4358 / ((LWP 4352 + LWP 4357)/2
DAY 270 1984 ITF2

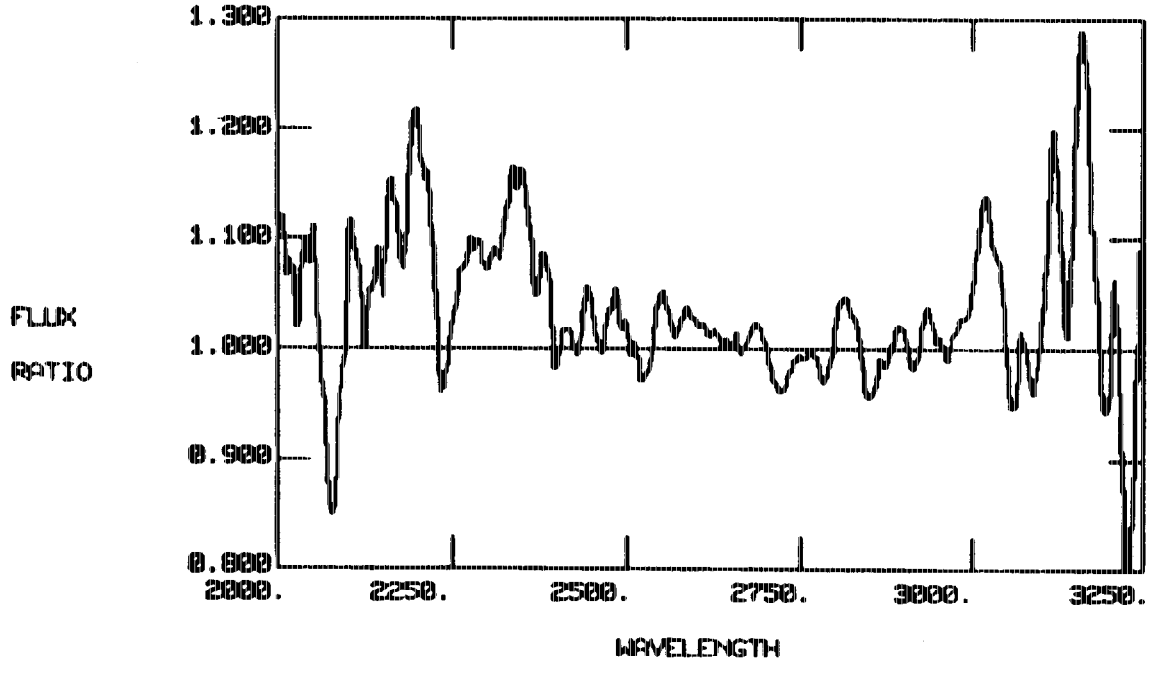


HD 6300 (30% + RADIATION) / 100%
LWP 4358 / ((LWP 4352 + LWP 4357)/2
DAY 270 1984 ITF1

Figure 9b



HD 6300 (60% + TFLOOD BACKGROUND) / 100%
LWP 4356 / ((LWP 4352 + LWP 4357)/2)
DAY 270, 1984 ITF2



HD 6300 (60% + TFLOOD BACKGROUND) / 100%
LWP 4356 / ((LWP 4352 + LWP 4357)/2)
DAY 270, 1984 ITF1

Figure 9c