

# The Photometric Accuracy of Images Read at 10 Kilobits per Second

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## Abstract

High dispersion SWP and LWP spectra of Eta UMa have been analyzed to determine what differences may exist in the photometric accuracy of images read at telemetry rates of 10 and 20 kbps. Five orders (73, 83, 93, 102, and 110) were studied in both cameras. SWP images read at 10 kbps appear to be statistically the same as those read at the normal 20 kbps. Somewhat larger uncertainties exist between LWP spectra read at 10 and 20 kbps, particularly at the higher orders.

In situations where the signal quality is marginal and maneuvering the spacecraft to a different attitude to read an image is not desirable, GOs may opt to read images at the lower telemetry rate to reduce the likelihood of losing data during the read. This technique is not recommended for programs where the highest photometric accuracy is required.

## Introduction

Interest in reading images at data rates lower than the usual 20 kilobits per second (kbps) arose when S-band power amplifier 4 (PA4) developed intermittent power fluctuations in 1984. PA4 is now in a low power state (down 10 db) virtually all the time, thus reducing the portion of the sky where error-free data can be reliably received from the antenna. This makes it difficult in many instances to efficiently observe targets when use of PA4 is required. If a lower telemetry bitrate could be used in certain situations, the Telemetry Handling System would be more likely to hold lock on the spacecraft signal.

For the Guest Observer, there are two factors affecting the desirability of reading an image at lower data rates. First, does the additional time required to perform the read scan adversely impact the observing program? Second, how well calibrated is the resulting spectrum? Since the read beam position is synchronized with telemetry, there is reason to believe there could be systematic differences in data quality between 10 and 20 kbps images.

## Observations

In order that a large portion of the image be examined for bitrate-dependent effects, high dispersion, rather than low dispersion, spectra of the same star were taken at 10 and 20 kbps. Seven LWP and seven SWP large-aperture high-dispersion spectra of Eta UMa (HD 120315) were taken in 1985 specifically for this study. The SWP images, SWP 26221-26227, were taken on 21 June 1985; each had an exposure time of 6.6 seconds. The LWP images, LWP 7192-7198, were taken on 26/27 November 1985; each had an exposure time of 5.5 seconds. Starting with 20 kbps, successive images were read at alternate bitrates (20 kbps, 10 kbps, 20 kbps, etc.). The standard camera preparation sequence (SPREP) following each read was performed at 20 kbps. SWP 26221 lost several minor frames of data during the read and was not used in the analysis; no other data dropouts occurred.

### Analysis

Six images (the second through the seventh in the sequence, see Table 1) for each camera were analyzed to study the accuracy of images read at 10 kbps. Five orders (73, 83, 93, 102, and 110) were analyzed for all images. The same analyses were performed on the data from both cameras. The majority of the study was of the gross and net flux numbers (FN); no ripple correction or absolute calibration was applied to the orders. The orders were resampled to a uniform wavelength spacing of 0.2 Angstroms.

The ratio of spectral orders from 10 and 20 kbps reads were examined to look for systematic differences. In addition, the ratio of spectral orders from images read at the same bitrate were computed to determine the overall repeatability of the high dispersion data and to provide data sets with which to compare the ratio of 10 and 20 kbps spectra. The ratio of net and gross spectra and their mean FN and standard deviation in a 10 Angstrom interval were computed for each order. The results are listed in Tables 2 and 3 for the SWP and LWP images, respectively. The "Image ratio" (1/3, 2/6, 3/4, etc) specifies where in the sequence the pair of images were taken. The odd and even numbers in the sequence refer to 10 and 20 kbps reads, respectively. The actual image numbers are given in Table 1. Tables 2 and 3 also contain the ratio of the mean 10 and 20 kbps spectra for each order.

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Table 1 -- Image Numbers and Bitrates for the 10 kbps Study

Sequence No.	Bitrate	LWP #	SWP #
1	10	7193	26222
2	20	7194	26223
3	10	7195	26224
4	20	7196	26225
5	10	7197	26226
6	20	7198	26227

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### Results

The comparison of the 10 and 20 kbps images reveals that the SWP spectra are very similar. The LWP images show some differences in the mean FN as large as 10 percent, particularly in the higher orders. The detailed results for each camera are discussed below.

#### a) LWP

The gross spectra from order 93 (0.2 A spacing) of the three 10 kbps reads and the three 20 kbps reads are plotted in Figure 1. There is general agreement in the orders from different images. The 10 and 20 kbps images have similar noise properties. The mean 10 kbps and mean 20 kbps gross spectra for orders 83, 93, 102, and 110 are plotted in Figure 2, again showing good agreement. However, the 10/20 kbps ratio for these orders plotted in Figure 3 reveal small systematic

differences of several percent. Near the ends of the orders these deviations increase to 10-15%. Figure 4 shows the ratio of 10 and 20 kbps mean net spectra for the four orders. Clearly the higher LWP orders are not in the best agreement, even though the ratios are close to one (see Table 3). The standard deviations for the mean net spectra in Table 2 are 1-3% larger than those for the mean gross spectra; this is also evident when Figures 3 and 4 are compared. As a final comparison of the 10 and 20 kbps images, Figure 5 show portions of orders 83 and 82, near the Mg II lines, with ripple corrections and the Cassatella (1985, Private Communication) LWP absolute calibration applied. The upper plot compares 10 and 20 kbps images. The lower plot compares two 20 kbps images. The orders are spliced near 2801 A. The agreement between the 10 and 20 kbps images is not obviously different than that between the two 20 kbps images.

#### b) SWP

The spectra from images read at 10 and 20 kbps are in overall better agreement than the LWP data. Figures 6-10 present the analagous results for the SWP as were shown in Figures 1-5 for the LWP. Ratios of 10 and 20 kbps data for gross and net spectra (Figures 8 and 9, and Table 2) are close to unity and have similar noise characteristics. Although the ratio of the gross spectra diverge from unity at the long wavelength end of the orders, the net spectra are flatter. This implies that the large errors in the gross spectra may be merely numerical artifacts which arise as the FNs approach zero. The flatter net spectra indicate the presence of a small systematic effect at low DN levels which is eliminated by the background subtraction. This effect would be in the sense of the 10 kbps images having slightly higher FNs than the 20 kbps images. A second possibility would be a small FN offset between the 10 and 20 kbps images, but there is no indication of this in Figure 7. In any case, after the ripple-corrected orders are spliced together this portion of the order does not contribute substantially to the calibrated spectrum. Finally, Figure 10 compares portions of orders 102 and 101, near the C II lines, to which ripple corrections and absolute calibration have been applied. The orders are joined near 1344 A. No significant differences are evident.

The only unusual behavior noted in the SWP data is in order 93 for both 10 and 20 kbps images. The ratios of 10 or 20 kbps spectra from SWP order 93 have standard deviations 3 to 4 times larger (see Table 2 and Figure 11) than ratios of other orders from the same images, and possibly systematic errors as well. This does not appear to be a bitrate-dependent effect. There is no obvious explanation why a portion of the image would behave differently only part of the time.

#### Conclusions

The photometric properties of SWP images read at 10 and 20 kbps are very similar and their differences statistically negligible. There are small differences in the spectra at the long wavelength end of the orders. The ratio of gross or net spectra from SWP order 93 shows noise characteristics larger than that from similar ratios for other orders. LWP images read at a 10 kbps telemetry rate appear to have statistically somewhat lower photometric accuracy than images read at 20 kbps, particularly for the higher orders. GOs may opt for reading images at the lower bitrate when data drop-outs are likely at 20 kbps and spectra of the highest photometric accuracy are not required.

Table 2

Binned SWP flux number ratios for images read at 10 and 20 kbps

<u>Gross Spectra</u>					
Image ratio	1885±5A order 73	1675±5A order 83	1480±5A order 93	1350±5A order 102	1252±5A order 110
10 kbps					
1/5	0.997±0.030	1.001±0.032	1.026±0.119	1.005±0.036	1.000±0.032
1/3	1.004±0.025	1.007±0.033	1.027±0.127	1.005±0.030	1.006±0.040
3/5	0.994±0.031	0.995±0.037	1.000±0.037	1.001±0.032	0.995±0.035
20 kbps					
2/4	1.000±0.033	1.009±0.046	1.030±0.131	1.008±0.029	1.008±0.029
2/6	0.998±0.029	0.998±0.031	1.030±0.129	1.001±0.030	1.001±0.039
4/6	0.999±0.028	0.991±0.040	1.000±0.031	0.993±0.030	0.993±0.037
10kb/20kb					
5/2	1.024±0.037	1.018±0.039	0.988±0.089	1.001±0.036	1.004±0.027
3/4	1.016±0.031	1.020±0.041	1.007±0.035	1.009±0.029	1.006±0.034
1/6	1.018±0.024	1.016±0.032	1.034±0.125	1.006±0.029	1.004±0.036
<10kb>/ <20kb>	1.019±0.018	1.018±0.021	1.006±0.023	1.005±0.017	1.004±0.017
<u>Net Spectra</u>					
Image ratio	1885±5A order 73	1675±5A order 83	1480±5A order 93	1350±5A order 102	1252±5A order 110
10 kbps					
1/5	0.992±0.035	0.989±0.042	1.022±0.172	0.998±0.050	1.002±0.047
1/3	0.998±0.031	1.002±0.046	1.030±0.182	1.001±0.043	1.007±0.057
3/5	0.995±0.037	0.989±0.051	0.995±0.051	0.998±0.045	0.997±0.052
20 kbps					
2/4	0.990±0.040	1.008±0.059	1.019±0.188	1.008±0.043	1.006±0.043
2/6	0.996±0.035	1.005±0.041	1.032±0.195	1.007±0.040	1.011±0.060
4/6	1.007±0.034	1.000±0.052	1.013±0.047	1.000±0.043	1.005±0.051
10kb/20kb					
5/2	1.014±0.043	1.005±0.050	0.987±0.110	0.997±0.051	0.997±0.043
3/4	0.997±0.038	1.000±0.053	0.981±0.049	1.001±0.040	0.998±0.051
1/6	1.001±0.029	0.998±0.044	1.023±0.191	1.001±0.041	1.008±0.053
<10kb>/ <20kb>	1.004±0.021	1.000±0.020	0.999±0.020	0.998±0.014	1.000±0.020

Table 3

Binned LWP flux number ratios for images read at 10 and 20 kbps

<u>Gross Spectra</u>					
Image ratio	3160±5A order 73	2785±5A order 83	2487±5A order 93	2265±5A order 102	2100±5A order 110
10 kbps					
1/5	0.983±0.126	0.995±0.043	0.996±0.052	0.999±0.058	0.975±0.073
1/3	0.967±0.117	0.996±0.044	1.001±0.050	1.003±0.060	0.987±0.054
3/5	1.022±0.106	0.999±0.043	0.996±0.047	0.998±0.050	0.989±0.065
20 kbps					
2/4	0.971±0.127	0.989±0.047	1.015±0.074	0.983±0.076	0.976±0.065
2/6	1.034±0.147	0.987±0.040	1.008±0.074	0.984±0.076	1.000±0.085
4/6	1.072±0.131	1.002±0.038	0.994±0.043	1.004±0.057	1.025±0.072
10kb/20kb					
5/2	1.113±0.133	1.026±0.048	1.015±0.058	1.044±0.079	1.049±0.088
3/4	1.089±0.126	1.009±0.037	1.022±0.043	1.019±0.067	1.006±0.054
1/6	1.115±0.160	1.005±0.037	1.015±0.051	1.021±0.054	1.015±0.072
<10kb>/ <20kb>	1.098±0.065	1.013±0.023	1.016±0.022	1.026±0.035	1.021±0.031
<u>Net Spectra</u>					
Image ratio	3160±5A order 73	2785±5A order 83	2487±5A order 93	2265±5A order 102	2100±5A order 110
10 kbps					
1/5	0.995±0.143	0.996±0.048	1.002±0.064	1.033±0.103	0.965±0.124
1/3	0.969±0.131	1.000±0.049	1.007±0.062	1.030±0.090	0.989±0.096
3/5	1.032±0.119	0.997±0.048	0.996±0.052	1.005±0.075	0.976±0.094
20 kbps					
2/4	0.996±0.134	0.990±0.054	1.031±0.083	1.036±0.129	0.988±0.105
2/6	1.013±0.145	0.985±0.044	1.020±0.082	1.013±0.120	1.008±0.135
4/6	1.024±0.127	0.996±0.043	0.991±0.049	0.980±0.068	1.023±0.108
10kb/20kb					
5/2	1.008±0.128	1.012±0.053	0.987±0.067	0.994±0.125	1.029±0.127
3/4	1.020±0.128	0.996±0.041	1.008±0.050	1.020±0.099	0.978±0.085
1/6	0.998±0.151	0.990±0.040	1.002±0.056	1.021±0.073	0.982±0.109
<10kb>/ <20kb>	1.002±0.064	0.999±0.025	0.997±0.028	1.007±0.051	0.991±0.049

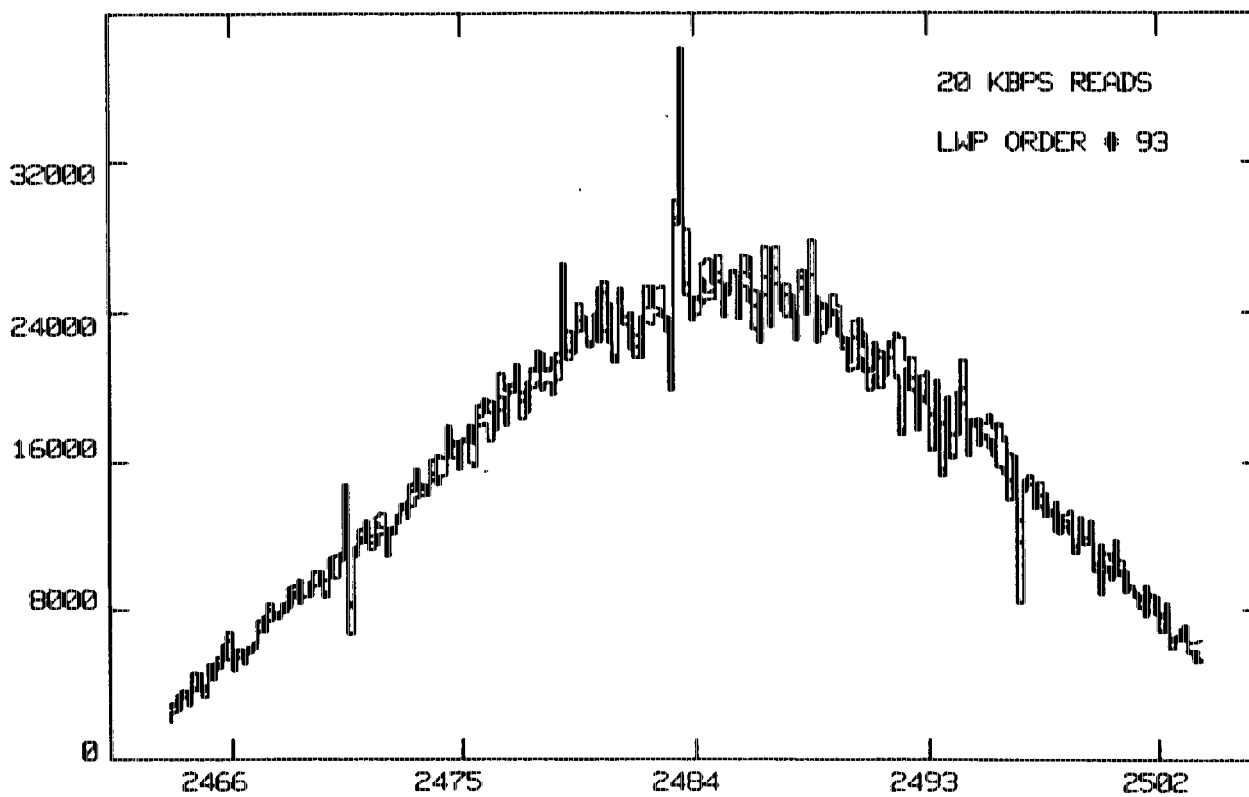
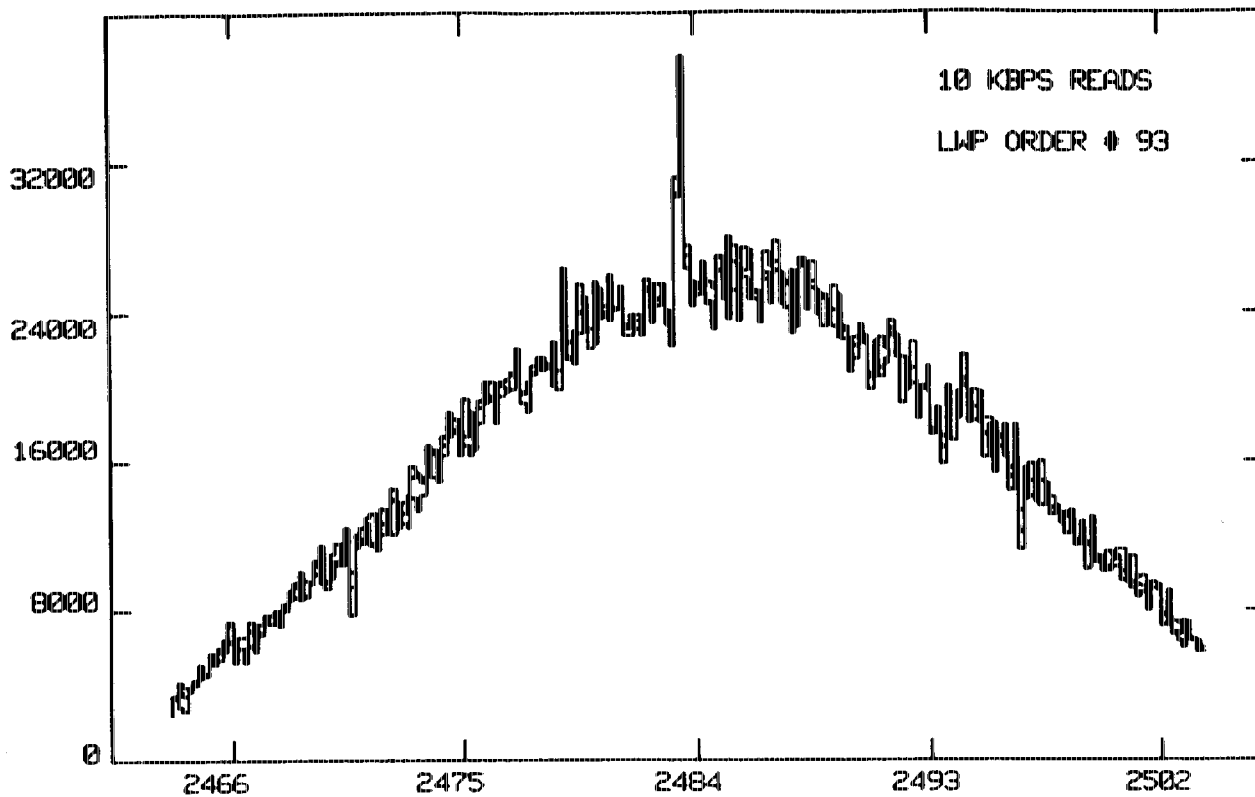


Figure 1 - LWP order 93 from the three 10 kbps images (upper panel) and from the three 20 kbps images (lower panel) are superposed on one plot.

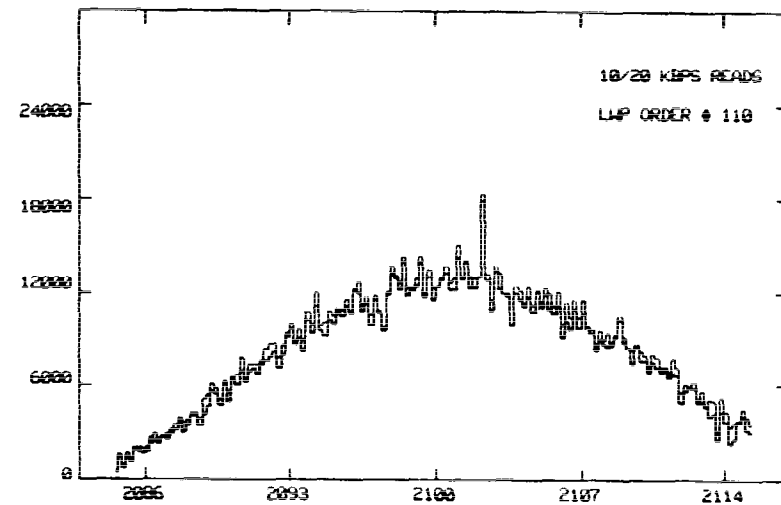
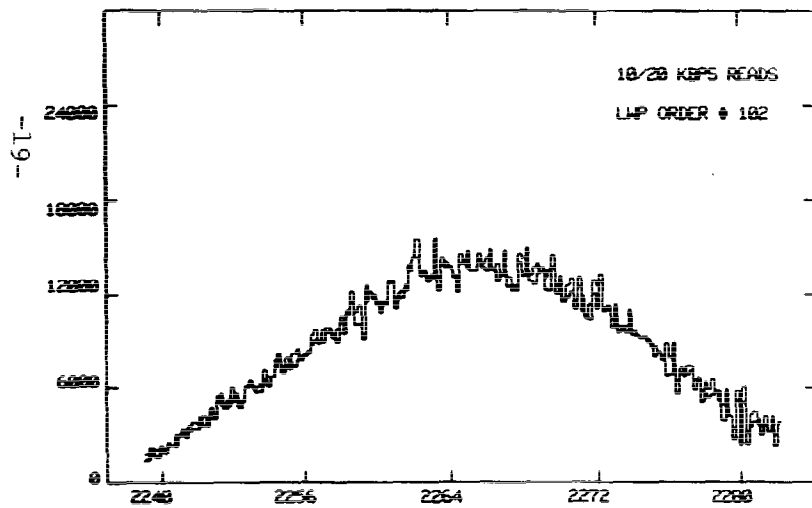
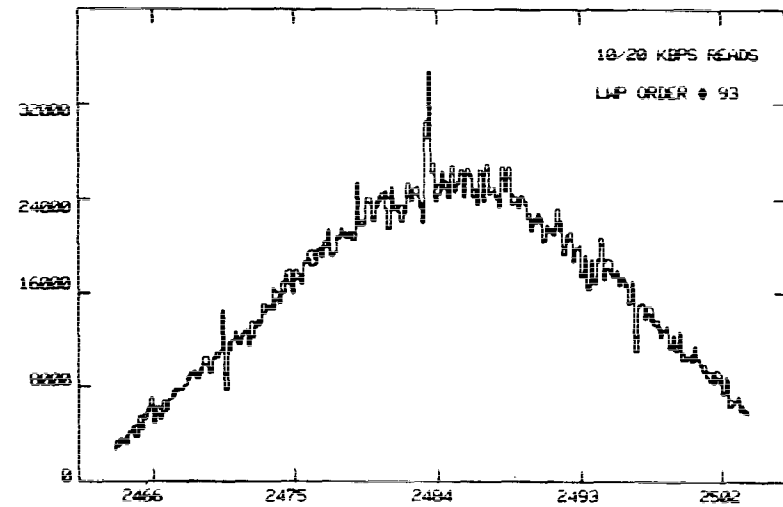
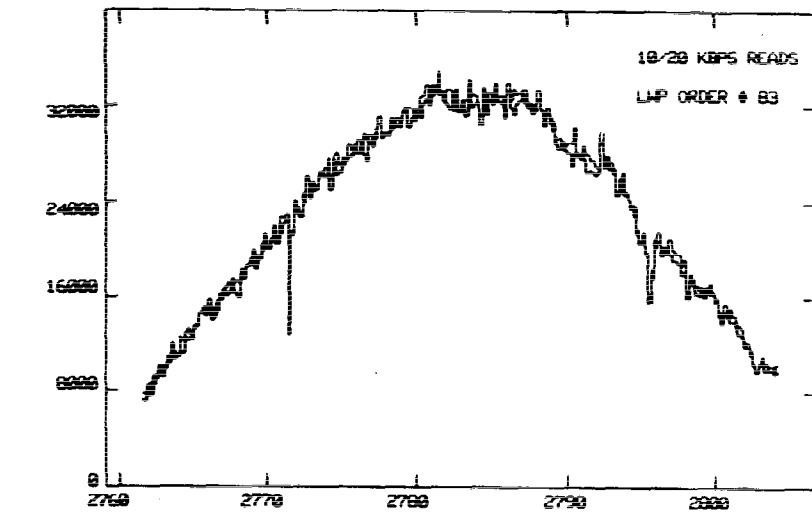


Figure 2 - The 10 and 20 kbps mean gross spectra are plotted together for orders 83, 93, 102, and 110.

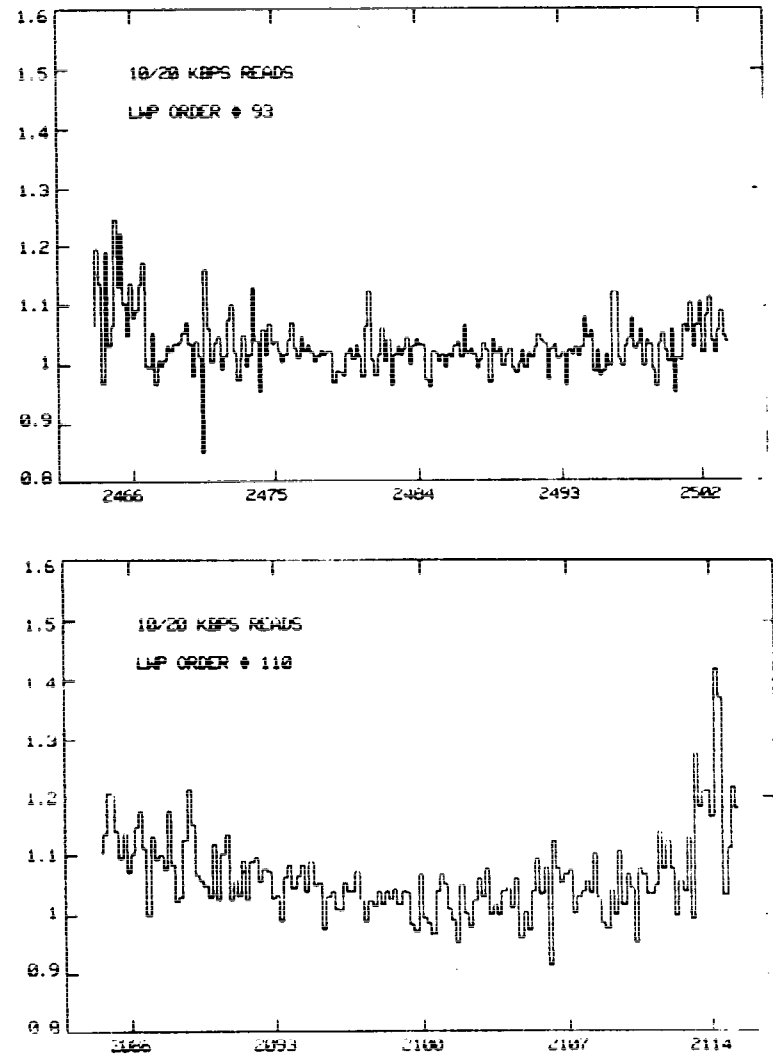
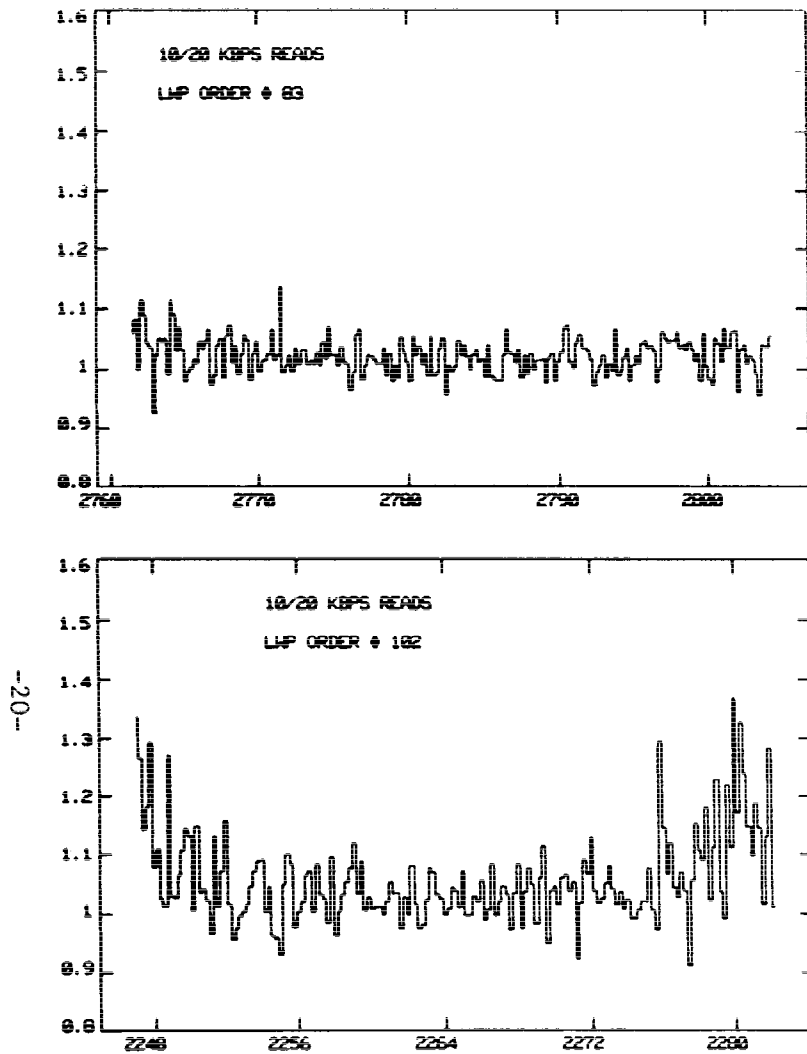


Figure 3 - The ratio of the 10 and 20 kbps mean gross spectra are plotted for orders 83, 93, 102, and 110.



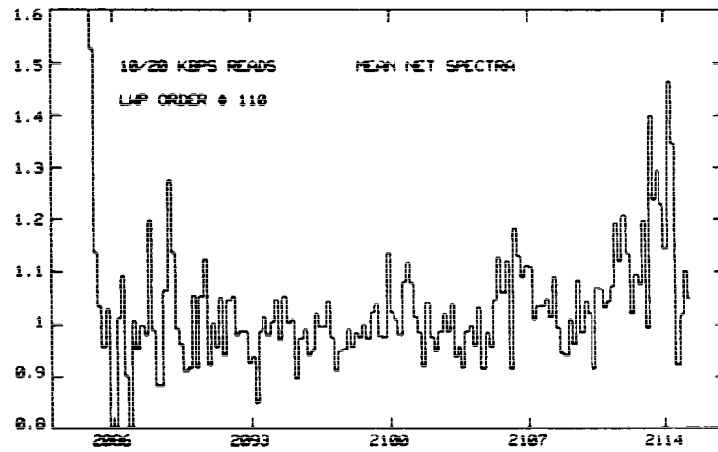
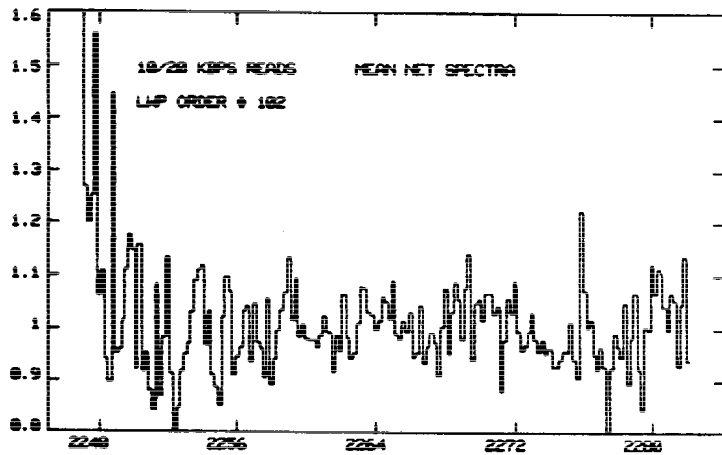
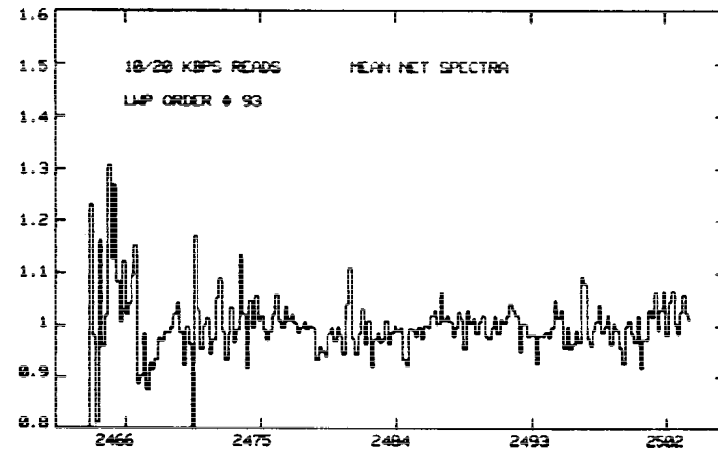
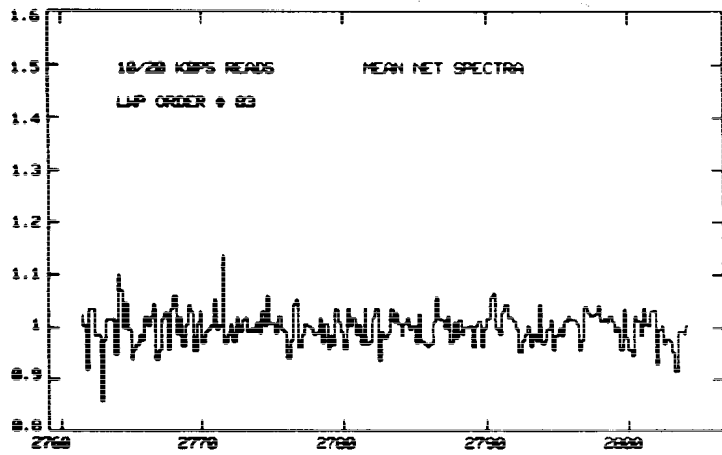


Figure 4 - The ratio of the 10 and 20 kbps mean net spectra are plotted for orders 83, 93, 102, and 110.

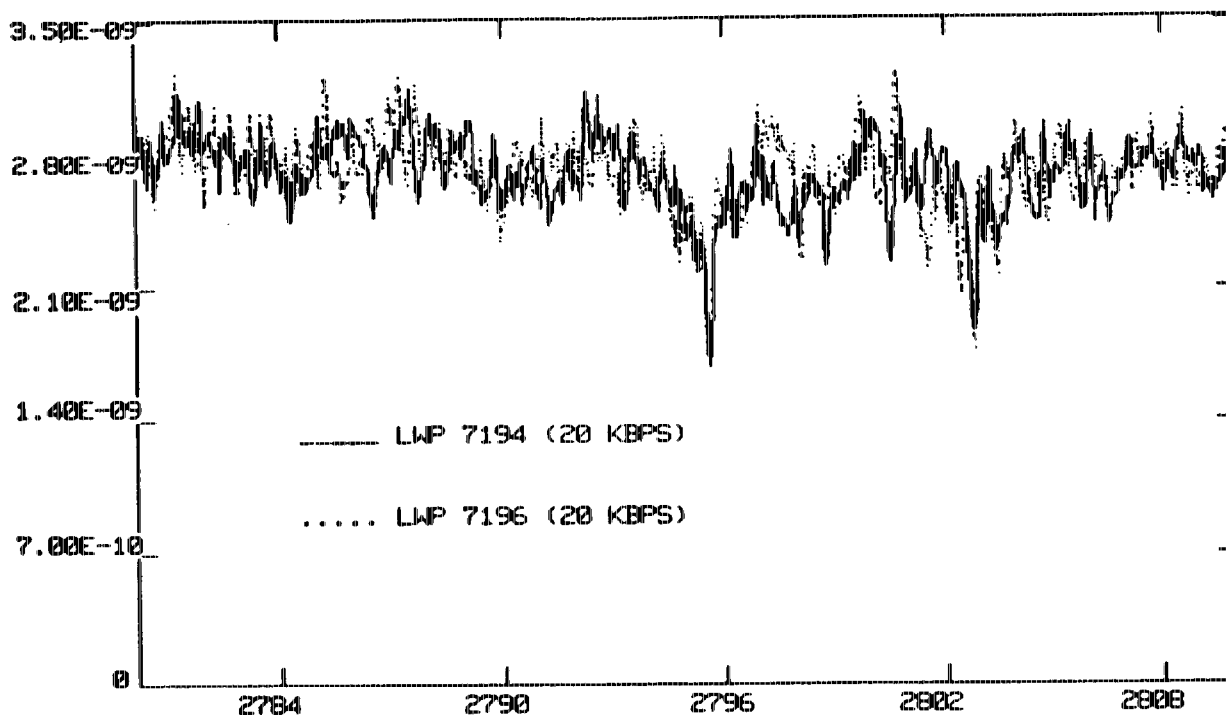
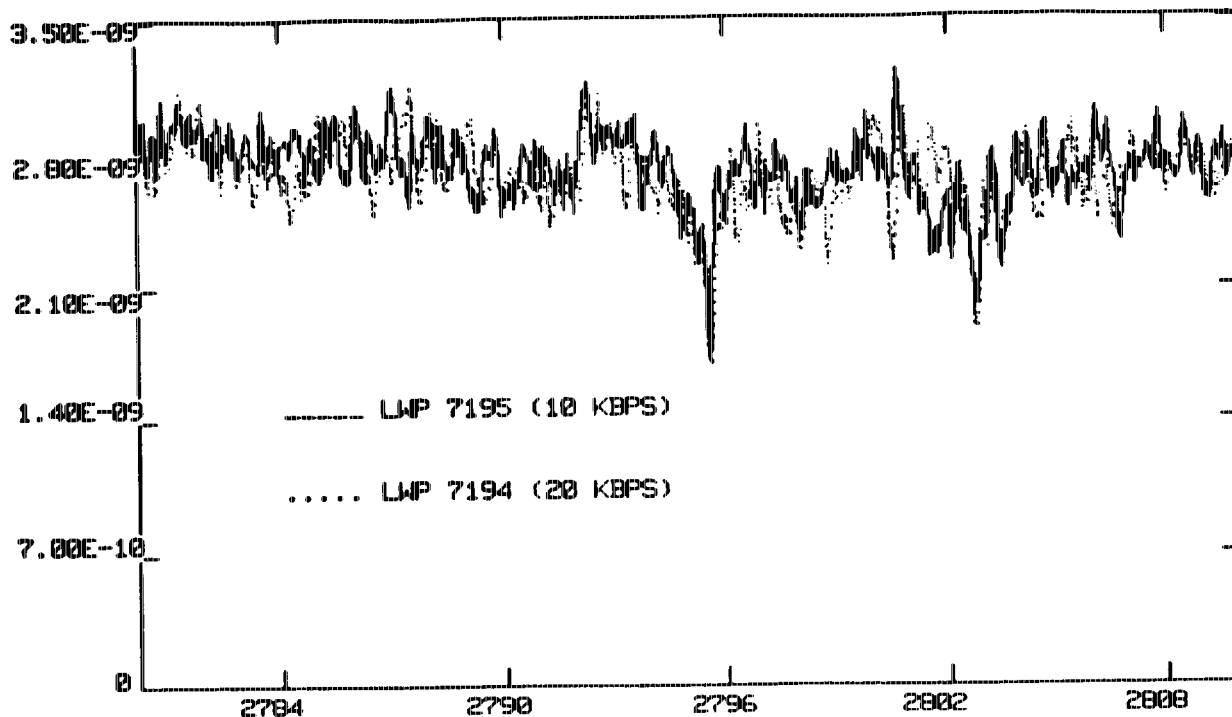


Figure 5 - Portions of orders 83 and 82 are compared for two 20 kbps images (lower panel) and for two 10 and 20 kbps images (upper panel). The orders are joined near 2801 A. Ripple corrections and the Cassatella (1985) absolute calibration have been applied to the spectra.

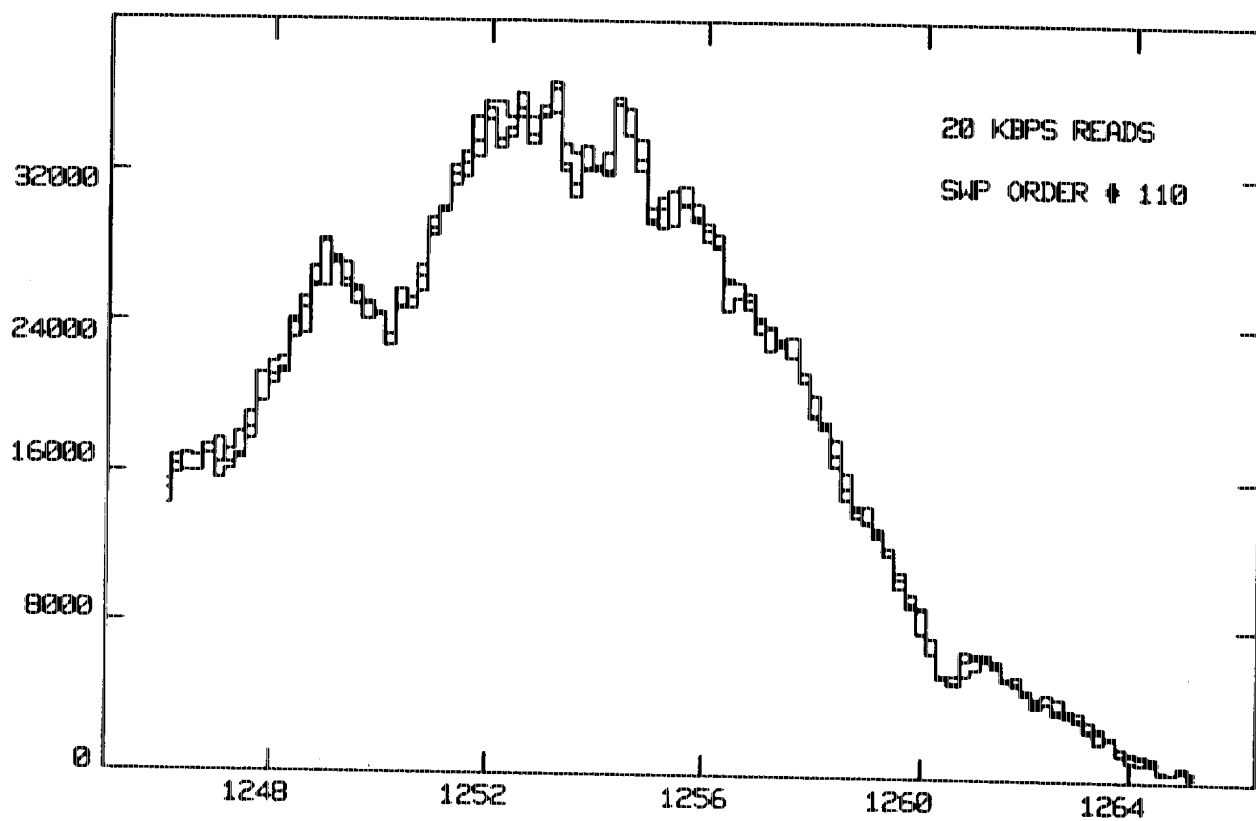
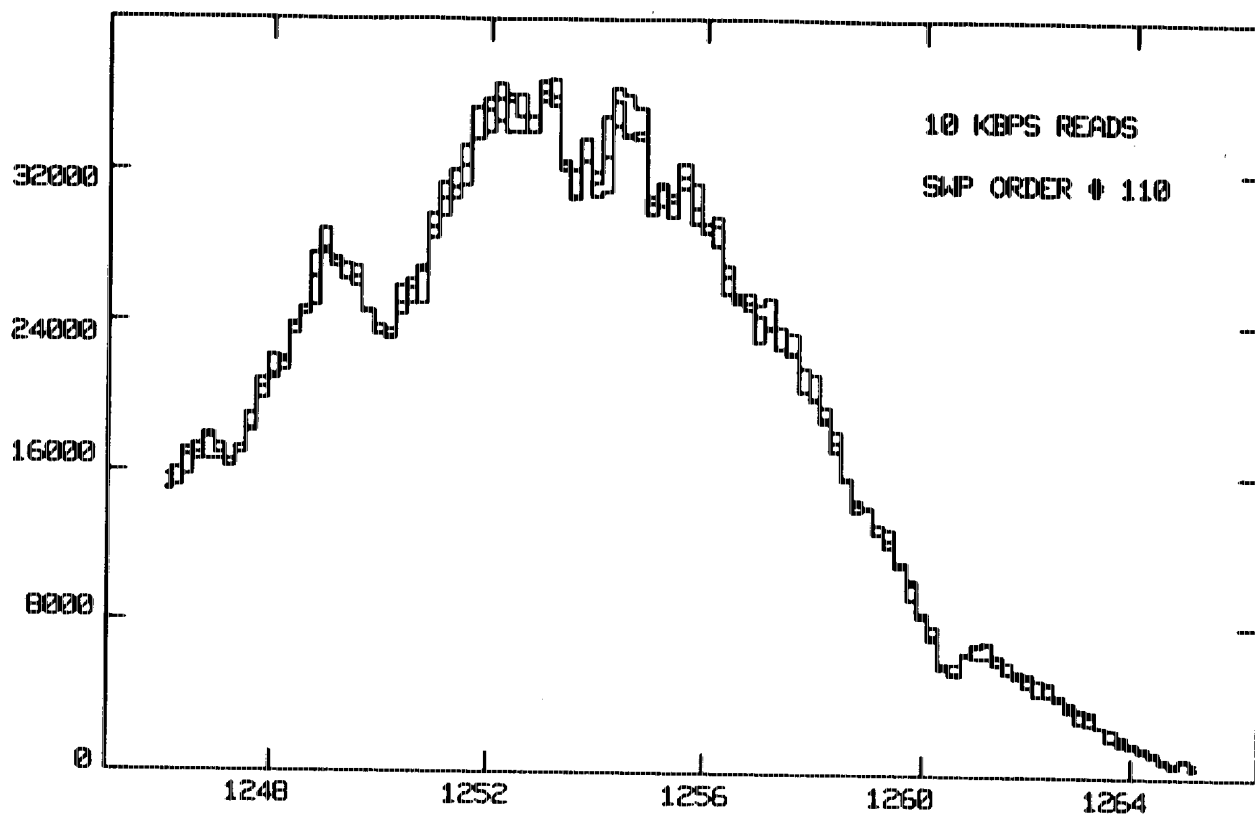


Figure 6 - SWP order 110 from the three 10 kbps images (upper panel) and from the three 20 kbps images (lower panel) are superposed on one plot.

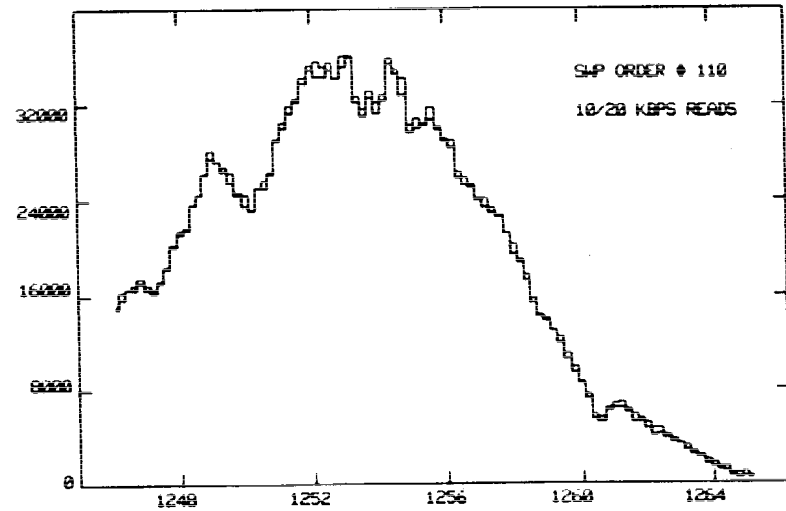
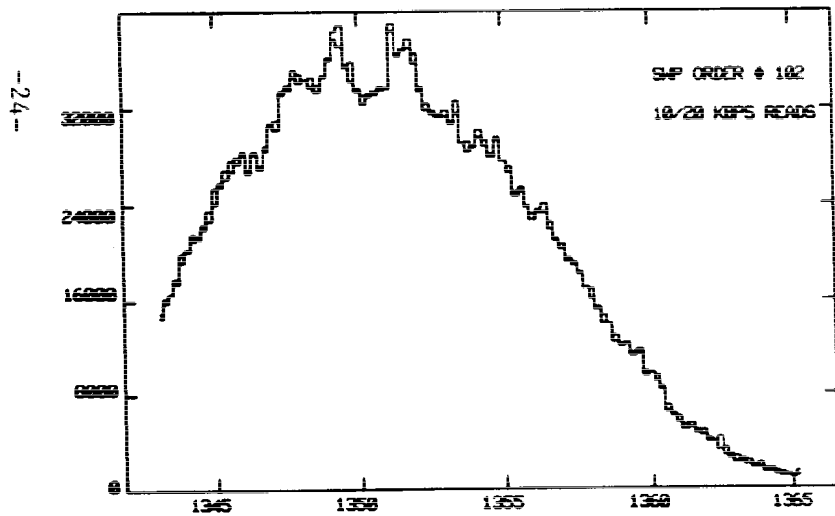
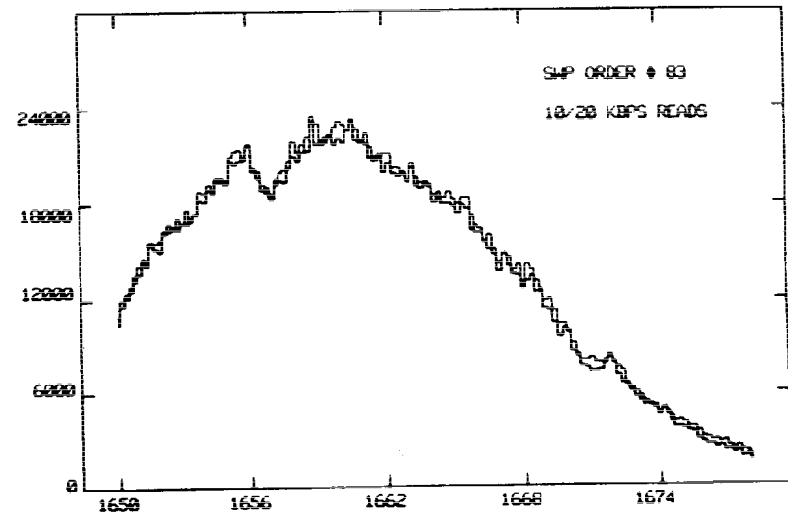
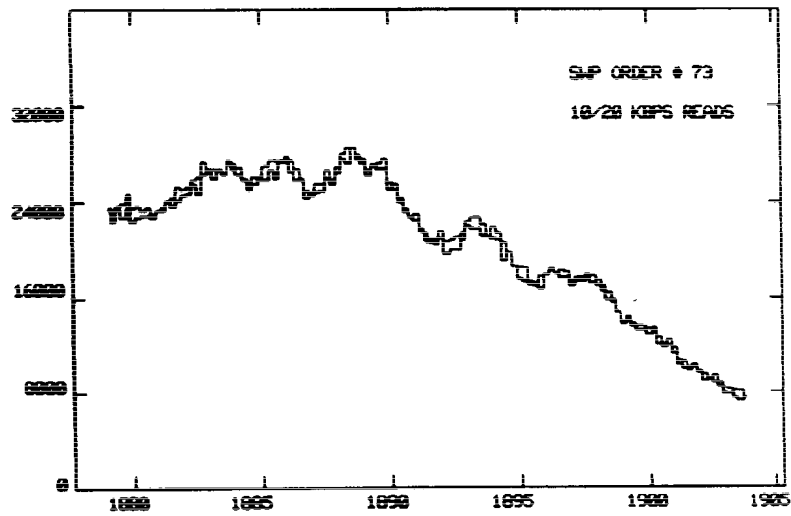


Figure 7 - The 10 and 20 kbps mean gross spectra are plotted together for orders 73, 83, 102, and 110.

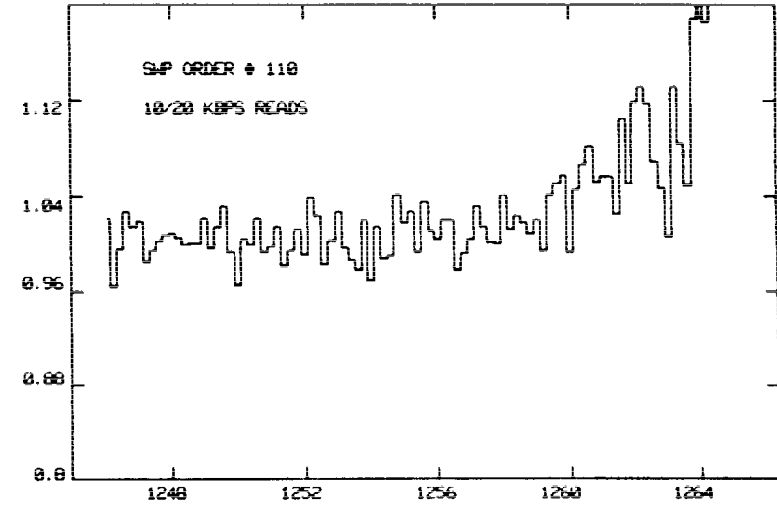
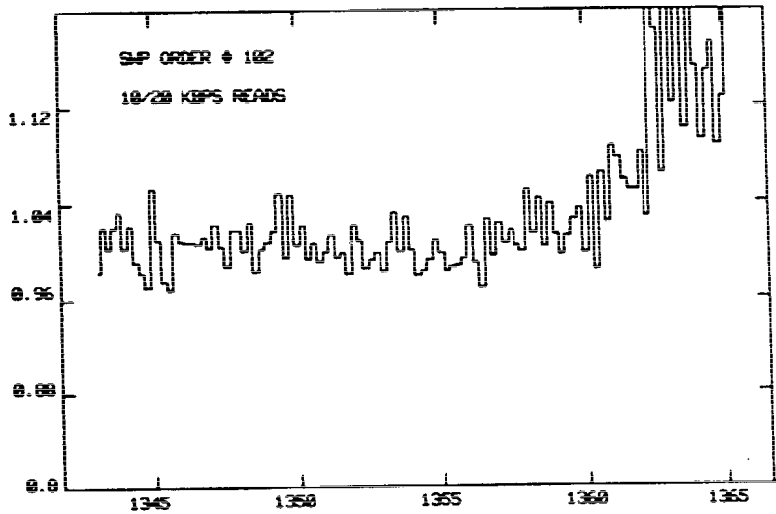
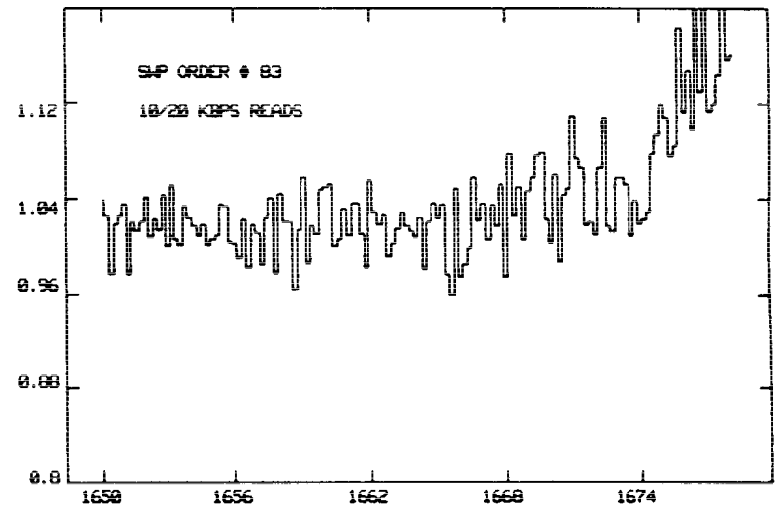
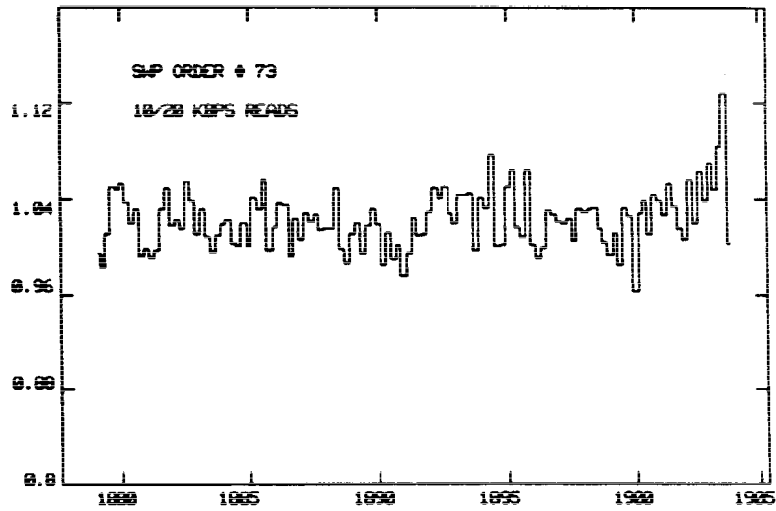


Figure 8 - The ratio of the 10 and 20 kbps mean gross spectra are plotted for orders 73, 83, 102, and 110.

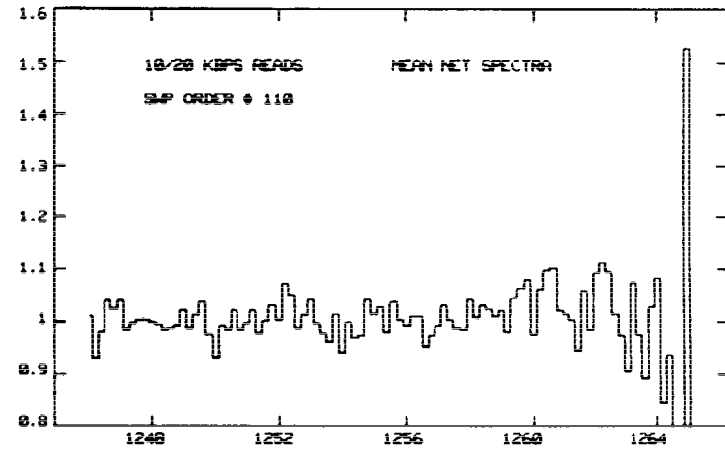
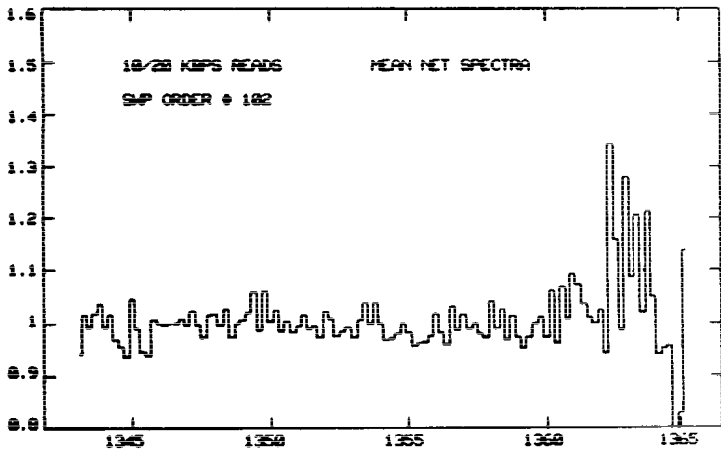
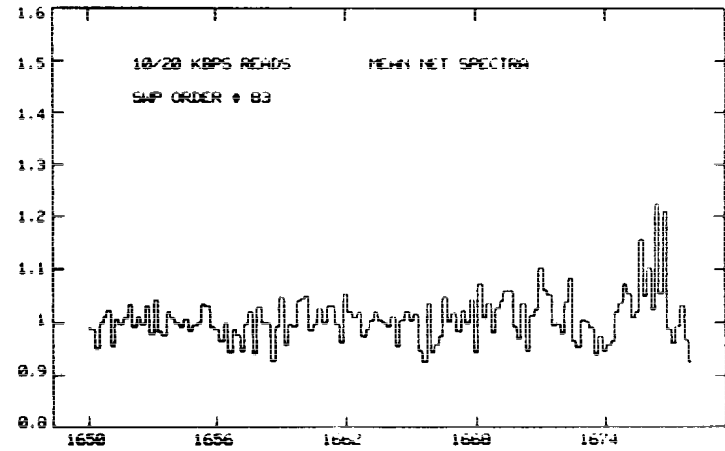
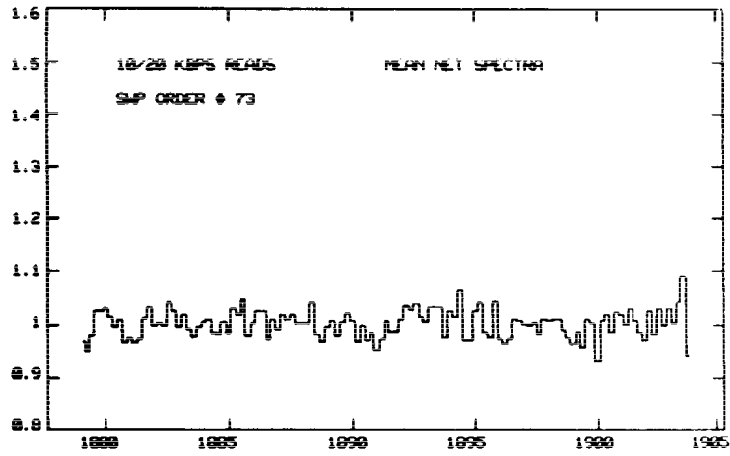


Figure 9 - The ratio of the 10 and 20 kbps mean net spectra are plotted for orders 73, 83, 102, and 110.

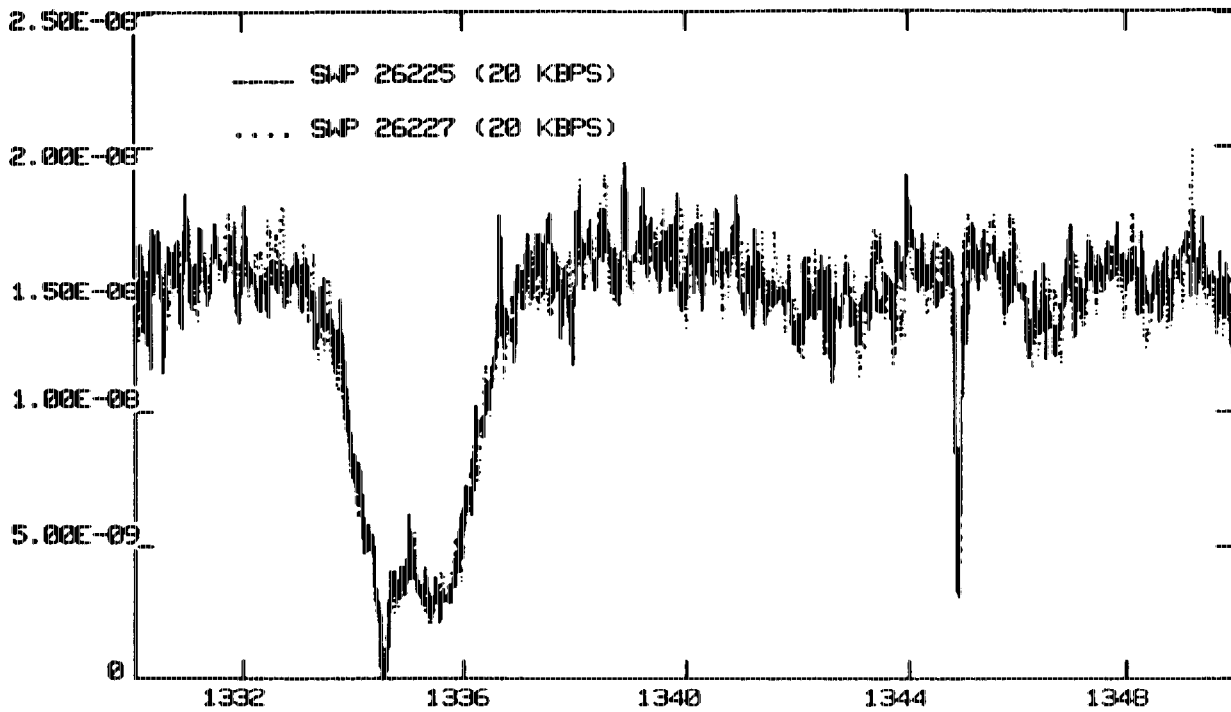
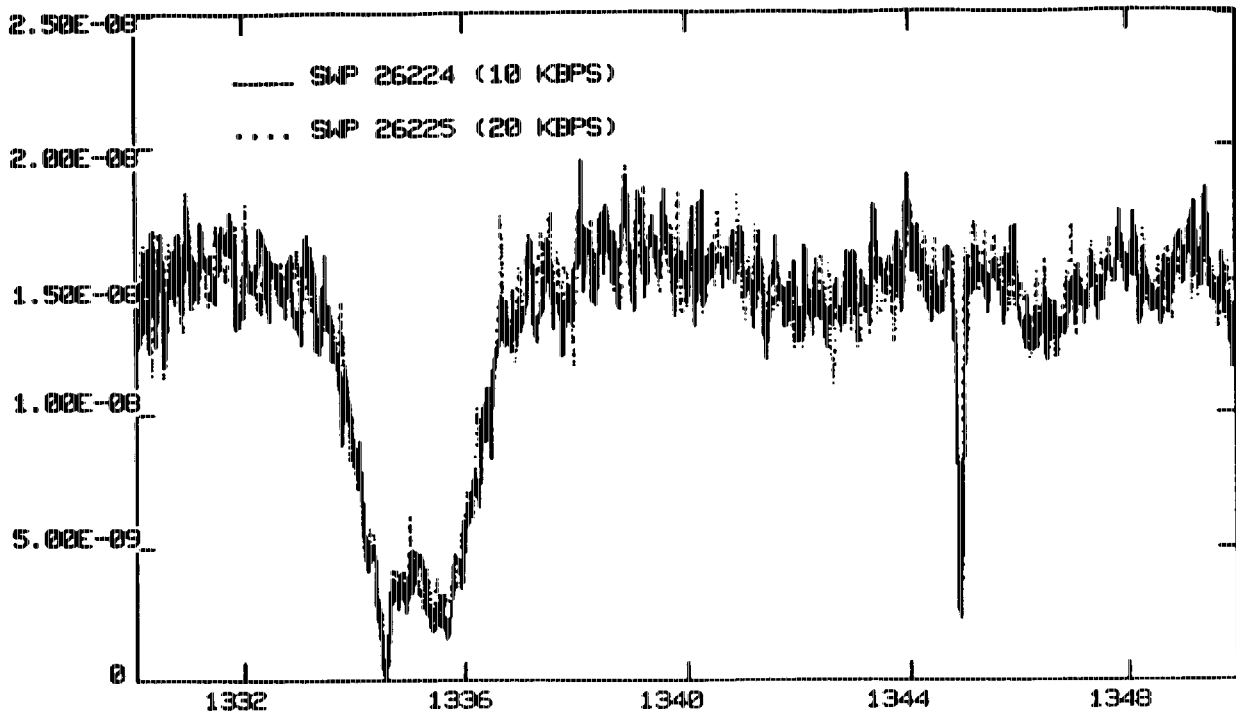


Figure 10 - Portions of orders 102 and 101 are compared for two 20 kbps images (lower panel) and for two 10 and 20 kbps images (upper panel). The orders are joined near 1344 Å. Ripple corrections and the absolute calibration have been applied to the spectra.

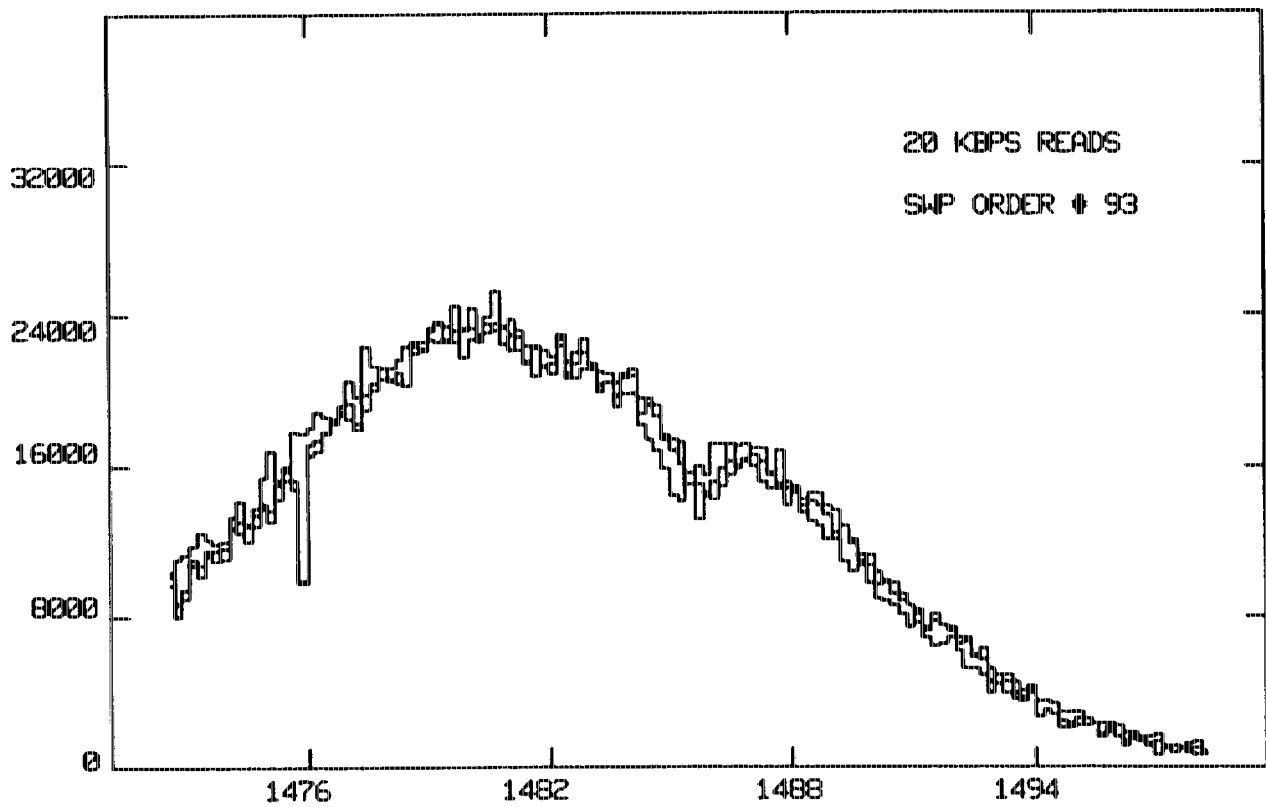
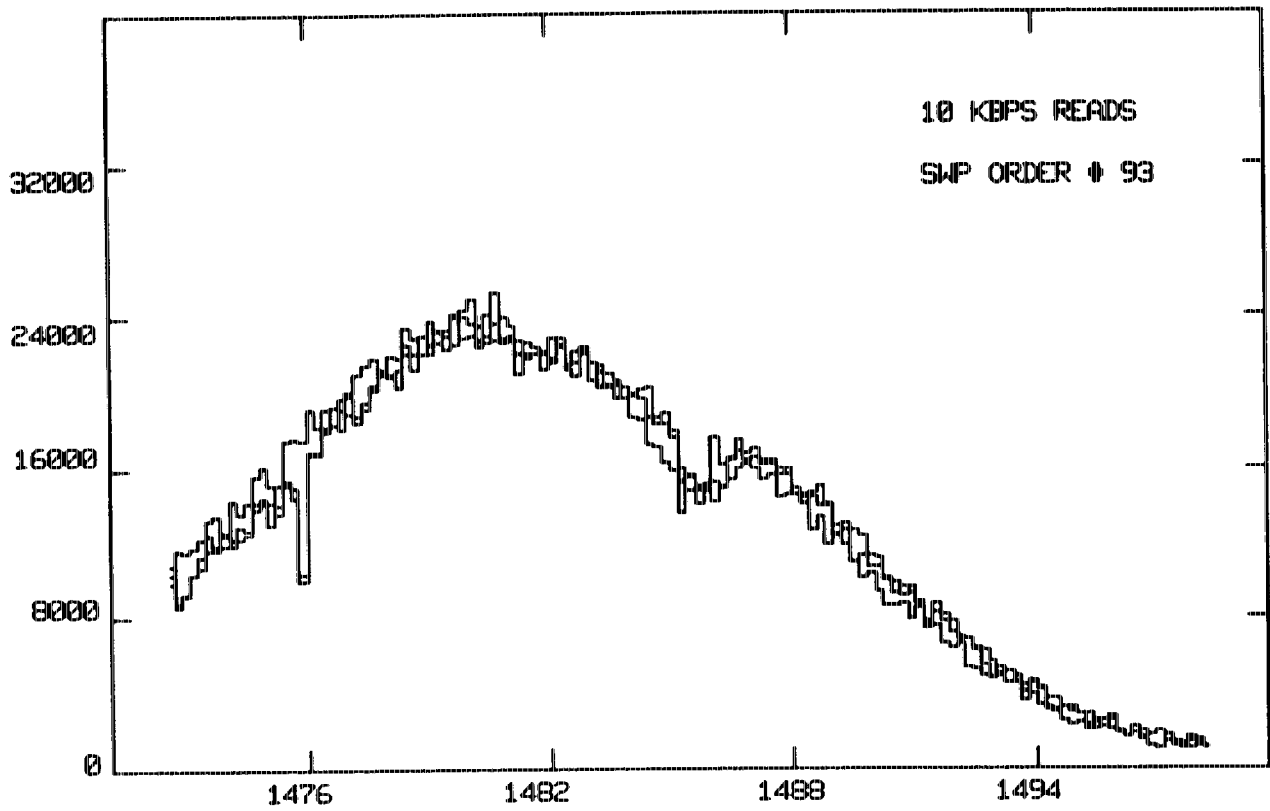


Figure 11 - SWP order 93 from the three 10 kbps images (upper panel) and from the three 20 kbps images (lower panel) are superposed on one plot. Note the large differences between the orders from different images read at the same bitrate.