**Apollo 17 Far-Ultraviolet Spectrometer Data Graphs: Microfilm Scans**

The Far-Ultraviolet Spectrometer Experiment (FUVS) on Apollo 17 consisted of an Ebert grating spectrometer mounted in the Scientific Instrument Module (SIM) bay of the Apollo 17 Command and Service Module. It provided observations of the lunar surface, lunar atmosphere, zodiacal light, solar atmosphere emissions, Earth emissions, and galactic and stellar emissions at wavelengths from 1184.00 to 1671.57Angstroms (118.400 to 167.157 nanometers). More detail on the FUVS is provided by Fastie (1973) and Fastie et al. (1973) and in the experiment description document for PDS (ID: urn:nasa:pds:apollodoc:a17doc:a17c_fuvs_overview).

This 16-mm film data set was supplied (originally on paper, microfilmed at the National Space Science Data Center, NSSDC) by the experimenter, Dr. Paul Feldman, and displays graphically some of the data from the Apollo 17 FUVS. The data are not in temporal order. They are displayed in two forms: averages of the counts in each spectral bin, and time variations in the intensities observed at a given wavelength. In general they appear to be data of interest that were plotted and saved by the experimenter. The experiment would run through the entire spectral range every 12 seconds, measuring each of the 115 spectral bins for 0.1 seconds before moving on to the next. One 12-second run through the entire wavelength range is referred to on the plots as a spectrum and given a number.

The count average plots (figure 1) showing the spectra are labeled identifying the five consecutive 12 second spectral runs used in the display and the actual elapsed time in hours, minutes, and seconds of the start of the first measurement run. The ordinate shows average counts per bin, each count record covering 0.1 seconds. The abscissa displays the bin number from 6 to 120. The bin number is equivalent to the word number, and represents the data word in the data record. Words 6 - 120 in the data record covered the data return, words 1 - 5 and 121 - 124 recorded other housekeeping data. Table 1 shows the wavelength range covered by each (36-bit) data word (bin) so the abscissa can be translated from bin number to wavelength range. The full range of the plot is from 1184.00 to 1671.57 Angstroms. The counts shown are the average observed counts in each separate bin over the 5 spectral runs, numbered 544-548. There are three variations of plots of this type, one has the header "AVERAGE OF THE SUM OF DECOMPRESSED COUNTS PER BIN" (see figures 1 and 3). This is a linear plot of the results. A second variation has the header "LOG (BASE 10) OF THE AVERAGE OF THE SUM OF THE DECOMPRESSED COUNTS PER BIN" (figure 4), this shows the same data as the first type on a log plot. The third variation of plot (figure 5) has no header and shows a lower counts/bin range to give a better view of the lower peaks in the spectrum.

The times on the plots are given in CTE (Computed Time Elapsed), which is the actual flight time - time in hours:min:sec since Apollo 17 launch on Dec. 7, 1972 at 05:33:00 UT. FUVS turn-on occurred at 81:37:30 CTE (15:10:30 UT Dec. 10) and transearth injection from lunar orbit began at 234:02:09 CTE (23:35:09 UT Dec. 16). Last FUVS data listed are CTE 299:31:22 (17:04:22 UT Dec. 19). Note that this is often referred to as Ground Elapsed Time (GET) but because the Apollo 17 mission launched 2 hours, 40 minutes later than originally scheduled, GET is sometimes used as time from scheduled launch, rather than time from actual launch, and the timeline was reset for this as well. We will only use CTE or UT in this description.

The term "decompressed" in the plot refers to a correction that was made to the raw data (P. Feldman, personal communication, 5 October 2018). The actual counts, S, differ from the raw observed counts, $C_{obs}$, due to a correction that must be made for counter dead-time according to (from National Space Science Data Center, National Data Center Information, Addendum J):

$$S = C_{obs} / [1 - ( C_{obs}\ ß)]$$

where $ß = 1.83 \times 10^{-5}$

The numbers on the plots are the corrected, or "decompressed" counts, greater than the observed counts, particularly at high counting rates.

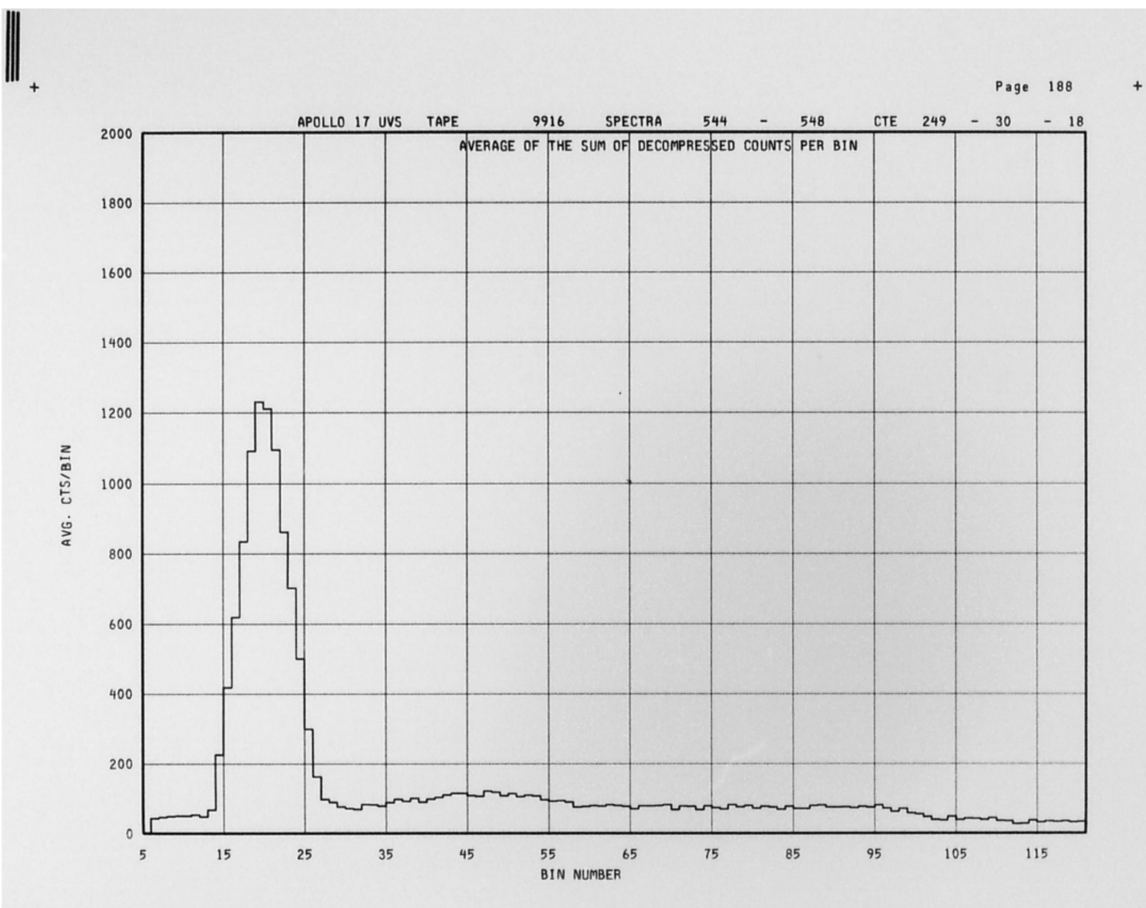


Figure 1 - Example of an average counts plot. This plot averages the five 12-second runs, or spectra, numbered 544-548, which started at CTE 249:30:18 (15:03:18 UT Dec. 17, 1972) .

The bin numbers along the abscissa can be translated to wavelength using table 1. The ordinate gives the average measured counts for the five 0.1-second measurements in each bin. In this example, the average counts per bin for the wavelength 121.567 nanometers (nm, bin 19, the highest point on the plot), or 1215.67 Angstroms, is approximately 1230.

The time-variation plots (figure 2) show the brightness in Rayleighs (ordinate) as a function of actual elapsed time expressed in decimal hours. Each frame covers 1 hour of data, and has the wavelength of the measurement (in Angstroms) printed near the top of the plot. The plots are typically ordered in groups of six different wavelengths. The wavelengths plotted vary from group to group, typically they are 1215.67 or 1215.70; 1236.00 or 1275.00; 1304.00; 1470.00; 1520.00, 1550.00 or 1556.00; and 1657.00 Angstroms. Some of the wavelengths are absorption bands for certain elements: 1215.70 (Hydrogen), 1304 (Oxygen), 1470 (Xenon), 1657 (Krypton). There are also a small number of time-variation plots on log scale.

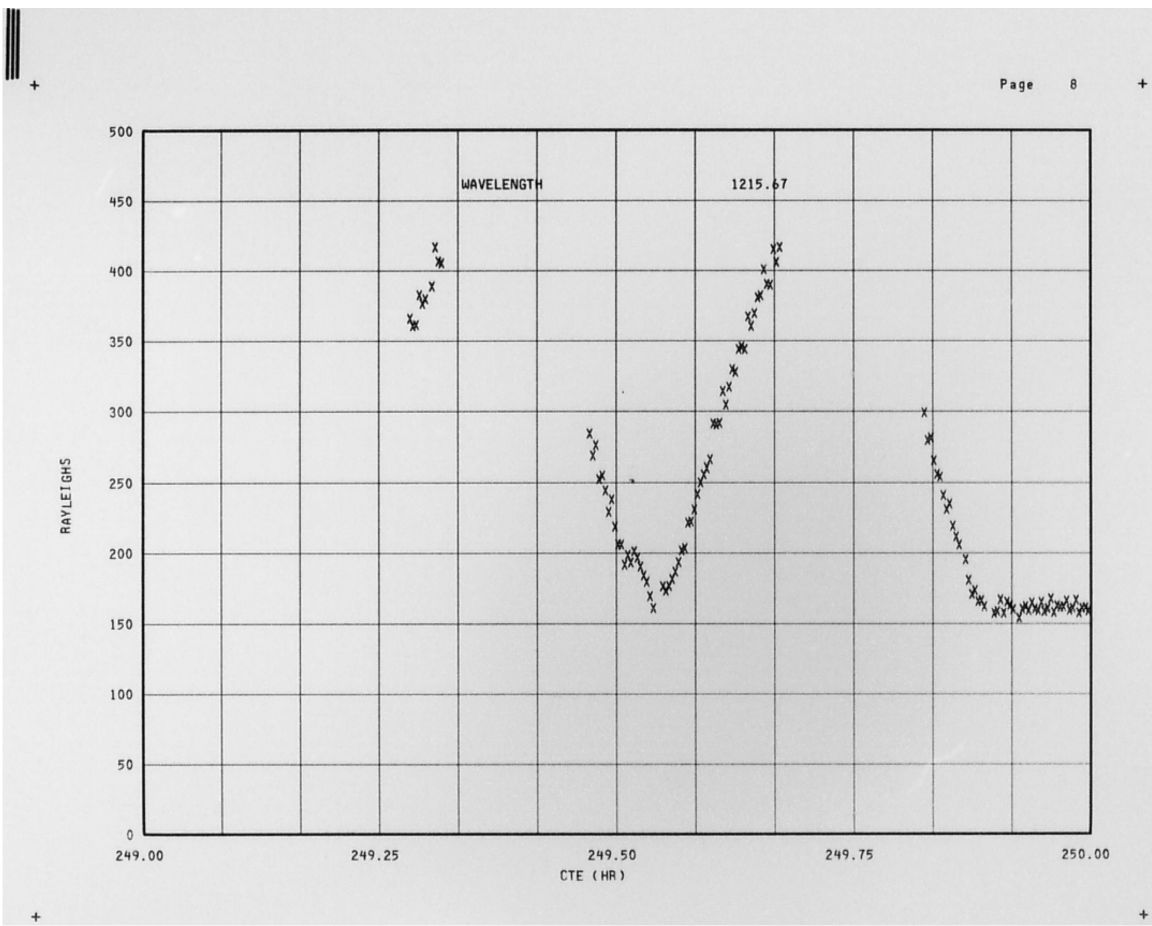


Figure 2 - Brightness for a given wavelength over a one-hour period, with the value in Rayleighs along the ordinate and the time in hours CTE along the abscissa. In this example, the brightness is given at wavelength 1215.67 Angstroms (121.567 nm) from time 249 to 250 CTE. At 249:30:18 CTE (249.505, the time of figure 1) the value is roughly 205 Rayleigh.

The average counts/bin value can be converted to brightness in Rayleighs. The basic equation for the conversion, taking into account all geometric factors, is (National Space Science Data Center, National Data Center Information, Addendum J):

$S = B\ 10^5\ A_s\ A_g\ Q\ D\ /\ 4\ \pi\ F^2$
$B = S\ 4x10^{-5}\ \pi\ F^2\ /\ A_s\ A_g\ Q\ D$

Where:

S = actual signal in counts per 0.1 second
B = Brightness in Rayleighs ($10^6$ photons/$cm^2$/second)
$A_s$ = slit area = 1.14 $cm^2$
$A_g$ = grating area = 104 $cm^2$
F = Focal length = 50 cm
Q = Quantum efficiency and transmission (QTPG). This is a wavelength dependent quantity; values are given in Table 2.
D = Degradation Factor, a time-dependent factor to account for the loss of efficiency of the instrument with time, see below.

Therefore, B = 0.00265 S/[Q D]

One correction, the degradation factor, D, is made to account for the degradation of the FUVS due to continuous exposure to solar Lyman-alpha radiation reflected by the Moon while in lunar orbit. The sensitivity of the instrument deteriorated in a linear fashion from instrument turn on at about 82 CTE to transearth injection at about 234 CTE. Upon departure from the Moon the FUVS was operating at 83% efficiency and there was no further degradation. The factor D can be modeled by:

$D = 1 - [0.17\ (T - 82)\ /\ 152]$

Where T is time in hours CTE listed on the plot, for all times before 234 CTE, and D = 0.83 for all times after 234 CTE.

Applying this to the values in figure 1 gives, for 1215.67 Angstroms (121.567 nm) at CTE 249:30:18 (249.505):

S ~ 1230 counts/bin/0.1 second (bin 19 - 121.461-121.627 nm, table 1)
Q = 0.0196 (table 2)
D = 0.83

B = (0.00265)(1230)/(0.83)(0.0196) = 200.4

which is close to the value in figure 2 at CTE 249.505.

This example matches well, but we note that comparison of the graphs can yield different values than would be given by the conversion. These conversions are contained in the documentation provided with the data set, the reason for the discrepancy between the equations and the graphs is not known.

| Word no. | Wavelength interval, nm | | Word no. | Wavelength interval, nm | |
|---|---|---|---|---|---|
| | From – | To – | | From – | To – |
| 6 | 118.400 | 118.409 | 66 | 143.997 | 144.357 |
| 7 | 118.409 | 118.905 | 67 | 144.357 | 144.595 |
| 8 | 118.905 | 119.450 | 68 | 144.595 | 144.808 |
| 9 | 119.450 | 119.767 | 69 | 144.808 | 144.967 |
| 10 | 119.767 | 119.946 | 70 | 144.967 | 145.144 |
| 11 | 119.946 | 120.133 | 71 | 145.144 | 145.316 |
| 12 | 120.133 | 120.299 | 72 | 145.316 | 145.454 |
| 13 | 120.299 | 120.522 | 73 | 145.454 | 145.634 |
| 14 | 120.522 | 120.738 | 74 | 145.634 | 145.808 |
| 15 | 120.738 | 120.935 | 75 | 145.808 | 145.959 |
| 16 | 120.935 | 121.114 | 76 | 145.959 | 146.141 |
| 17 | 121.114 | 121.285 | 77 | 146.141 | 146.318 |
| 18 | 121.285 | 121.461 | 78 | 146.318 | 146.464 |
| 19 | 121.461 | 121.627 | 79 | 146.464 | 146.603 |
| 20 | 121.627 | 121.788 | 80 | 146.603 | 146.744 |
| 21 | 121.788 | 121.972 | 81 | 146.744 | 146.913 |
| 22 | 121.972 | 122.148 | 82 | 146.913 | 147.054 |
| 23 | 122.148 | 122.312 | 83 | 147.054 | 147.251 |
| 24 | 122.312 | 122.480 | 84 | 147.251 | 147.387 |
| 25 | 122.480 | 122.638 | 85 | 147.387 | 147.535 |
| 26 | 122.638 | 122.776 | 86 | 147.535 | 147.694 |
| 27 | 122.776 | 122.916 | 87 | 147.694 | 147.853 |
| 28 | 122.916 | 123.040 | 88 | 147.853 | 148.022 |
| 29 | 123.040 | 123.211 | 89 | 148.022 | 148.196 |
| 30 | 123.211 | 123.403 | 90 | 148.196 | 148.378 |
| 31 | 123.403 | 123.571 | 91 | 148.378 | 148.567 |
| 32 | 123.571 | 123.711 | 92 | 148.567 | 148.742 |
| 33 | 123.711 | 123.867 | 93 | 148.742 | 148.887 |
| 34 | 123.867 | 124.017 | 94 | 148.887 | 149.015 |
| 35 | 124.017 | 124.131 | 95 | 149.015 | 149.289 |
| 36 | 124.131 | 124.224 | 96 | 149.289 | 149.883 |
| 37 | 124.224 | 124.315 | 97 | 149.883 | 150.648 |
| 38 | 124.315 | 124.683 | 98 | 150.648 | 151.448 |
| 39 | 124.683 | 125.410 | 99 | 151.448 | 152.222 |
| 40 | 125.410 | 126.182 | 100 | 152.222 | 152.978 |
| 41 | 126.182 | 126.987 | 101 | 152.978 | 153.681 |
| 42 | 126.987 | 127.711 | 102 | 153.681 | 154.402 |
| 43 | 127.711 | 128.399 | 103 | 154.402 | 155.092 |
| 44 | 128.399 | 129.164 | 104 | 155.092 | 155.821 |
| 45 | 129.164 | 129.870 | 105 | 155.821 | 156.591 |
| 46 | 129.870 | 130.616 | 106 | 156.591 | 157.371 |
| 47 | 130.616 | 131.383 | 107 | 157.371 | 158.071 |
| 48 | 131.383 | 132.109 | 108 | 158.071 | 158.784 |
| 49 | 132.109 | 132.826 | 109 | 158.784 | 159.589 |
| 50 | 132.826 | 133.543 | 110 | 159.589 | 160.334 |
| 51 | 133.543 | 134.209 | 111 | 160.334 | 161.074 |
| 52 | 134.209 | 134.998 | 112 | 161.074 | 161.778 |
| 53 | 134.998 | 135.722 | 113 | 161.778 | 162.505 |
| 54 | 135.722 | 136.376 | 114 | 162.505 | 163.287 |
| 55 | 136.376 | 137.059 | 115 | 163.287 | 163.987 |
| 56 | 137.059 | 137.790 | 116 | 163.987 | 164.764 |
| 57 | 137.790 | 138.513 | 117 | 164.764 | 165.535 |
| 58 | 138.513 | 139.216 | 118 | 165.535 | 166.247 |
| 59 | 139.216 | 139.908 | 119 | 166.247 | 166.972 |
| 60 | 139.908 | 140.643 | 120 | 166.972 | 167.157 |
| 61 | 140.643 | 141.363 | | | |
| 62 | 141.363 | 142.087 | | | |
| 63 | 142.087 | 142.793 | | | |
| 64 | 142.793 | 143.484 | | | |
| 65 | 143.484 | 143.997 | | | |

Table 1 - Word numbers (= Bin Numbers) and associated wavelength range

Table III. Calibration Data

| Wavelength (A) | QTPG | Photoelectrons/sec/R |
|---|---|---|
| 1192 | .0163 | 61.5 |
| 1216 | .0196 | 74 |
| 1280 | .0263 | 99 |
| 1336 | .0251 | 95 |
| 1395 | .0233 | 88 |
| 1463 | .0200 | 75.5 |
| 1518 | .0156 | 59 |
| 1582 | .0093 | 35 |
| 1608 | .0079 | 29.8 |
| 1639 | .0070 | 26.4 |
| 1655 | .0078 | 29.4 |

Table 2 - Quantum efficiency and transmission (QTPG) along with instrument sensitivity in photoelectrons/second/Rayleigh as a function of wavelength. This table was extracted from the National Space Science Data Center, National Data Center Information, Addendum J, which is an Information Sheet associated with the Far-UV Spectrometer Data collection on tape, PSPA-00070, held at the NSSDCA. This sheet also states that during the mission, the sensitivity of the instrument deteriorated due to continuous exposure to solar Lyman-alpha radiation reflected by the Moon. During transearth coast, the sensitivity was reduced by 83% of the value given in this calibration table.

The two plots shown above (figures 1 and 2) include observations made at hour 249.5 CTE at wavelength 1215.67 for comparison. All images in this dataset are high-resolution scans (400 dots per inch) of plots on microfilm held in NSSDCA (NASA Space Science Data Coordinated Archive) data collection PSPA-00203, Far-Ultraviolet Spectrometer Data on Microfilm.

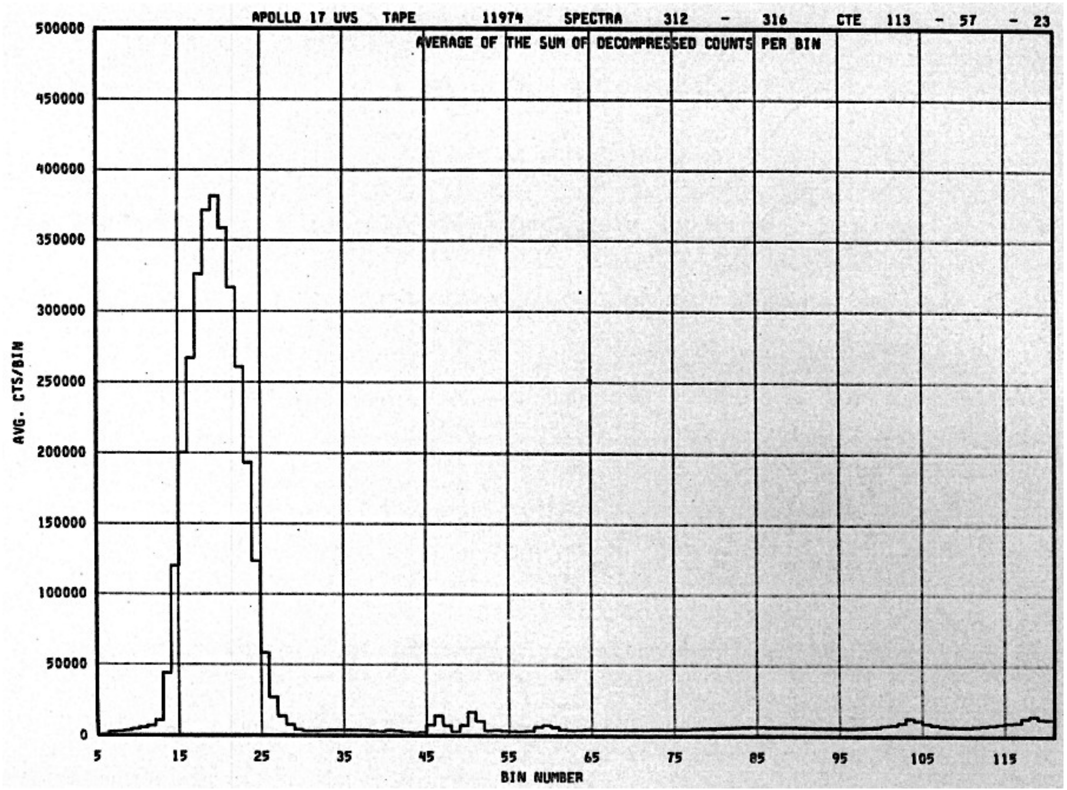


Figure 3 – Example plot of the average of the sum of decompressed counts per bin for spectra 312-316, CTE 113:57:23.

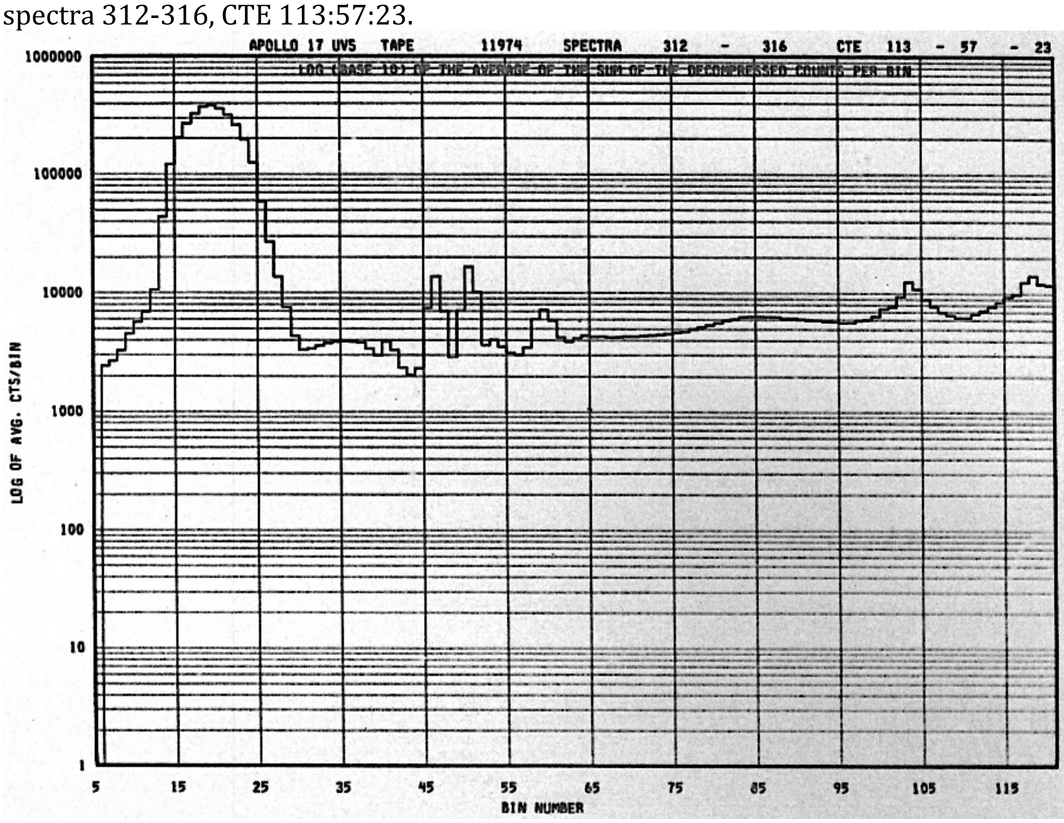


Figure 4 – Example plot of the log (base 10) of the average of the sum of the decompressed counts per bin plot for spectra 312-316, CTE 113:57:23.

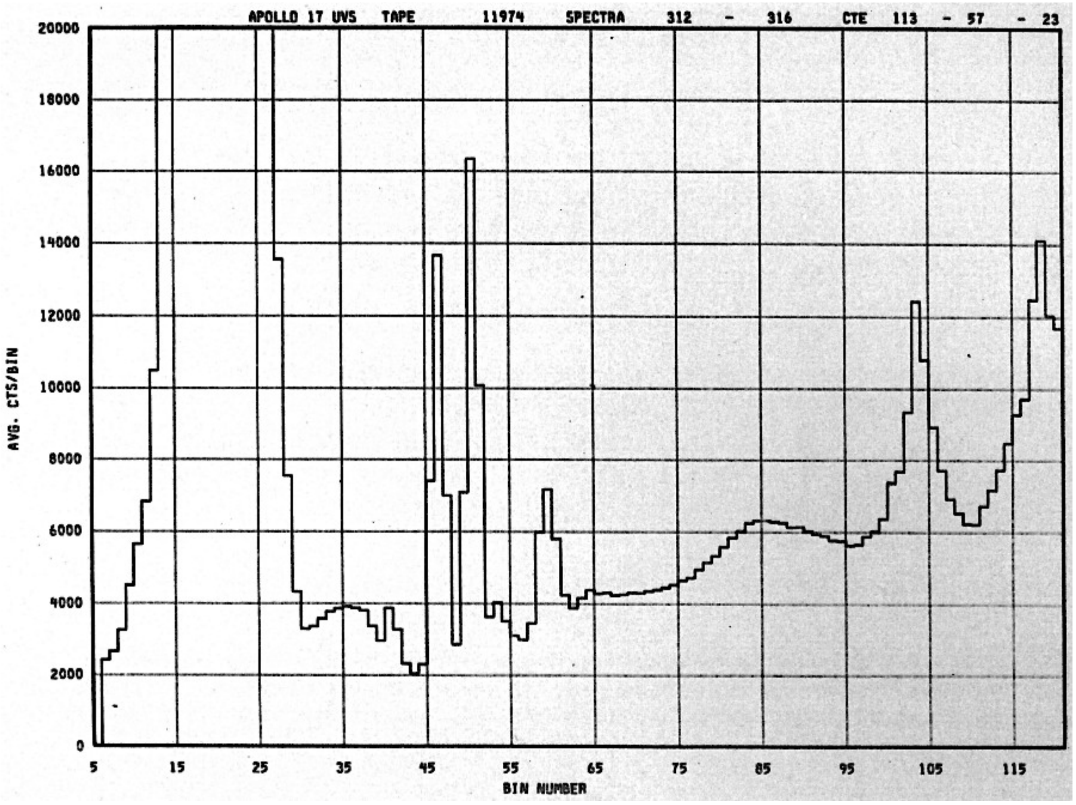

Figure 5 – Example plot of the average of the sum of decompressed counts per bin for spectra 312-316, CTE 113:57:23, with the upper limit truncated to 20,000 to cut off the peaks and allow higher resolution of the lower values.

Caution should be exercised in the use of these plots, some contain noisy data and will give unphysical results. All frames of the microfilm were scanned, some of the frames do not contain any obviously useful information but were included for completeness.

## References

Fastie, W.G., The Apollo 17 Ultraviolet Spectrometer Experiment, The Moon, 7, 49, 1973. (doi:10.1007/BF00578807 or available from the NSSDCA as publication B18698-000A)

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Fastie, W.G., Final Report - Apollo 17 Ultraviolet Spectrometer Experiment (S-169), Johns Hopkins University Dept. of Physics, NASA CR-140316, 1974. (NSSDCA publication B22822-000A, available from the NASA Technical Reports Server, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19750002056.pdf)

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Feldman, P.D., and D. Morrison, The Apollo 17 Ultraviolet Spectrometer: Lunar atmosphere measurements revisited, Geophys. Res. Letts., 18, 11, 2105-2108, 1991. (doi: 10.1029/91GL01998)

Lauderdale, W. W., and W. F. Eichelman, Apollo Scientific Experiments Data Handbook, NASA, TM-X-58131, Houston, Tex., Aug. 1974. (Available from the NASA Technical Reports Server, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19760007062.pdf)

National Space Science Data Center, National Data Center Information, Addendum J, Apollo 17 Ultraviolet Spectrometer Experiment, Data Format, undated. (Included in documentation, note error in 2nd equation, $10^{-6}$ should be $10^{6}$)