**EARTH-BASED NEAR-INFRARED COLLECTION OF SPECTRA FOR THE MOON: A NEW PDS DATA SET.** C. M. Pieters[1] and S. Pratt[1] [1]Brown University (Department of Geological Sciences, Providence RI 02912; pieters@geo.brown.edu)

**Introduction:** Near-infrared spectroscopic data for the Moon acquired with earth-based telescopes will be available to the community in PDS format in the spring of 2000 after final stages of peer-review. These data will allow coordinated analyses of the NIR multispectral images from Clementine with higher resolution spectroscopic data. The PDS Geosciences Node will oversee the data availability. Examples of spectra are shown in Figure 1.
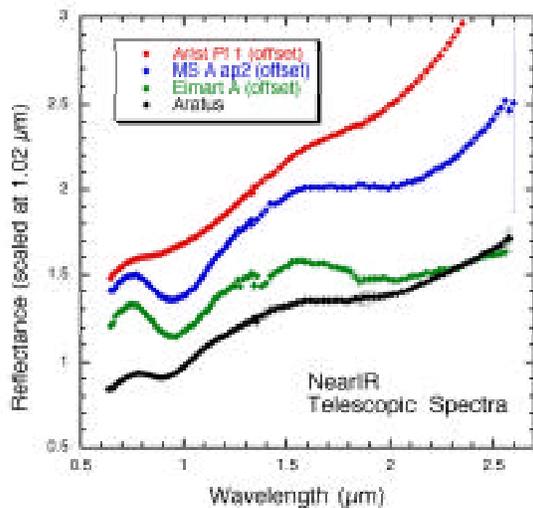


Figure 1. Examples of the nearIR telescopic spectra for the Moon. These data are of the highest quality rating and show some of the diagnostic absorption bands near 1 and 2 µm. The top spectrum exhibits glass features of the pyroclastic deposits on the Aristarchus Plateau. The remaining spectra are for small craters and exhibit features do to pyroxene of various compositions ± olivine.

**Description**. Several hundred spectra have been acquired from 0.65 to 2.5 µm for small (3 to 10 km diameter) areas on the lunar surface. Several PI's have been involved in data acquisition including B. R. Hawke, P. Lucey, T. B. McCord, C. M. Pieters, and several of their students and associates. Multiple publications have contained subsets of the data. A review of data acquired for highland craters and the procedures used to process the data can be found in [1]. All data were acquired using telescopes at Mauna Kea Observatory (MKO) on Hawaii, which is located at an elevation of almost 14,000 feet (4200 m). This is one of the few earth-based observatories that provides two essential conditions for this type of data: 1) sufficiently low atmospheric absorption, especially in the near-infrared water bands, to allow an adequate signal for a

continuous spectral measurement to 2.5 µm and 2) good to excellent 'seeing" (a term in astronomy used to describe the general turbulence of the earth's atmosphere that limits the clarity and resolution of an image).

Most of the lunar reflectance data were taken with the University of Hawaii/NASA 2.2m (88-inch) telescope, using either a f10 or f35 secondary mirror. The highest spatial resolution (~3km) required exceptionally still atmospheric conditions using a small spectrometer aperture at f35 near full moon when the reflected flux is highest. Only about 5% of the data were obtained under these optimal conditions. About a third of the spectra were measured using a 60-cm (24-inch) telescope. These lower spatial resolution data, obtained early in the program, concentrated on soils in the maria which are relatively homogeneous at the observed scale.

The near-infrared spectrometer used for these measurements was developed by T. B. McCord in the mid-1970s explicitly for planetary spectroscopy needs and is described in [2]. The detector used is a liquid nitrogen-cooled InSb (indium antimonide) single detector. Spectral coverage is obtained by sweeping through a circular variable filter in 120 steps, providing a spectral resolution of about 100Å from 0.6 to 1.4 µm and 200Å from 1.35 to 2.5 µm. Each such sweep, of 'data run", takes a little less than 2 minutes and must be repeated many times on the object being measured, as well as on a calibration standard (star or lunar landing site). For each data measurement a dark background, or sky, measurement is obtained. During data acquisition a photograph (or video) is obtained of the lunar area as it is seen on the mirrored aperture, to be used as documentation for area location. Raw data are viewed on a monitor during data acquisition and stored on magnetic tape with observational parameters for later processing.

For lunar data, the calibration standard used is normally an area near the Apollo 16 landing site. Prior to 1980 an area in mare Serenitatis (MS2) was used as a lunar standard with earlier instruments [3] because there are no nearby albedo features that can add unwanted spurious data if the area is not properly located through the telescope. With this near-infrared spectrometer on the MKO 2.2-m telescope, the spatial resolution is sufficiently high to allow accurately repeated measurements of a homogeneous area of Cayley Formation continuous with, but located about 10 km to the west of, the Apollo 16 site. This Apollo 16 standard is measured every 15 to 25 minutes to monitor the atmospheric extinction and calculate appropriate signal adjustments with time.

The raw data are converted to reflectance measure-

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ments through a data processing sequence that includes the use of laboratory reflectance measurements of a carefully chosen returned mature soil from Apollo 16 (62231).  The use of lunar soil as a calibration standard has been found to be more accurate for these telescopic reflectance measurements than using 'solarlike' stars or stellar models [4]. A flux ratio is produced for the flux of an area under study divided by the flux from  the Apollo 16 standard site and this ratio is multiplied by the laboratory reflectance  measurement of Apollo  16 soil.  For these near-IR telescopic data, a directional hemispheric measurement of Apollo 16 soil acquired by J. B. Adams was used.  [This spectrum can be seen in [5] and will be included with the PDS data files.] The first flux ratio in this data processing is a relative reflectance measurement.  It provides atmospheric and instrumental  calibration,  but  still  includes observational and statistical errors of repeated measurements. The precision of the reflectance data depends on this ratio, which I turn also depends on the observing conditions and the number of times an independent measurement is made.  The second ratio, the laboratory measurement of 62231, is quite precise.  The laboratory standard, halon, has been calibrated as an absolute reflectance standard with reflectance values of 97% to 99% in the near-infrared.  Since albedo data are  not derived in this data processing sequence, lunar reflectance data are scaled to unity at ~1,02 µm since there are no major  atmospheric absorptions at that wavelength.

There are three major sources of error that are not easy to  separate for these  reflectance measurements. The first is statistical and is dependent on the sensitivity and stability of the detector.  Normally, this source of error is the smallest and is less than 1% after averaging four to six measurements.  The second is atmospheric transparency and stability. This is not only often the largest source of error, it as also the least predictable and controllable.   The  procedure described above eliminates most of the systematic atmospheric variations, but nothing can effectively be done about the  smaller-scale  atmospheric  turbulence  that  earth-based  telescopes  must  tolerate.  The  third  source  of error arises from the difficulty in repositioning the telescope at precisely the same lunar location for each observation *and* keeping it pointed at the *same* lunar location (within a fraction of an arcsecond)  throughout the measurement sequence.  For surfaces that contain significant small-scale albedo variations, these pointing errors can create signal variations that mimic spectral variations (since they are measured sequentially). The error bars normally plotted with a measured reflectance spectrum are the statistical variations (standard deviation) between repeated measurements of the object area and the standard area during the night.  The error bars thus only record the random repeated variations of the measurements  and  are  not  sensitive  to  any  slightly systematic  or  discontinuous  variations  that  occurred over the period of the measurements (about 1.5 hr). For complex  surface  areas,  it  is  thus  important  to  have more than one completely independent measurement of the spectrum for interpretations.

Many lunar spectra, especially those from the highlands,  exhibit  a  change  of  continuum  slope  near 1.6µm. Some of the continuum shape at longer wavelengths is real, but the telescopic data may also include a minor (<10%) thermal component  of  radiation increasing beyond about 2.2 µm.  This occurs when the lunar area and the standard area are observed at greatly different illumination (thermal conditions). This thermal component can mimic variations of the weak 2.0 µm pyroxene absorption band and must be accurately determined  before  the  band  center  can  be  estimated with confidence.  Removal of the thermal component, which varies with the position of the subsolar point on the lunar surface, is theoretically possible [6], but reliable  estimates  require  accurate  determination  of  the temperature  of  the  lunar  areas  when  reflectance  data were obtained.

In addition to standard PDS labels, data provided to PDS includes the name of the lunar location, it's lunar coordinates, a tentative classification, the scaled reflectance values, standard deviation of the  measurements (as described above), and a qualitative quality assignment made by the people acquiring the data.

**References**:
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