Lunar Surface Features: Mid-Infrared Spectral Observations

Abstract. *The moon has been observed and spectrally scanned at mid-infrared wavelengths, in particular through the 16- to 24-micron atmospheric window. The data indicate that there are differences in mineral composition among several features of the lunar surface.*

Ground-based observations of features of the lunar surface have been made at mid-infrared wavelengths to determine the feasibility of obtaining compositional as well as thermal data through the windows in the earth's atmosphere.

The vibrational resonance frequencies of silicate rocks and minerals (of which the earth's surface is principally composed) all occur at wavelengths longer than 8 μ. However, most information from the spectrum—characteristic frequencies which are diagnostic of composition—is contained in two regions centered near 10 and 20 μ. The grouping of such data is illustrated in Fig. 1, which presents the infrared reflection spectra of several representative polished rock samples. The data were recorded at room temperature in a Perkin-Elmer model 521 spectrophotometer equipped with a double beam reflection attachment. Additional data can be obtained by extending the range into the far infrared.

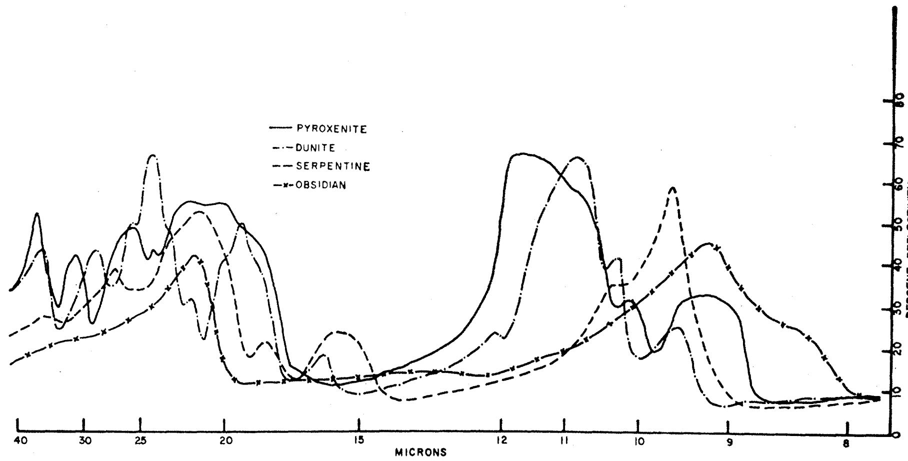

Fig. 1. Reflection spectra of polished rock samples recorded on Perkin-Elmer model 521 spectrophotometer. Angle of incidence 13 deg.

Calculations indicate that for wavelengths shorter than about 3 μ, most of the energy coming from the lunar surface at full moon is reflected light from the sun, whereas at wavelengths longer than 3 μ most of the energy is emitted from the hot lunar surface. The limit to which this energy can be detected is about 40 μ.

Van Tassel and Simon (*1*) have demonstrated that the extent of the spectral data obtained in the emission from solids depends primarily upon the state of aggregation, or particle size, of the emitting sample; the more finely divided the sample, the more closely its emission approaches that of a black body, and characteristic spectral information is lost. However, they demonstrated that in the 8 to 14 μ region, good spectral data were retained down to sand-sized particles. Figure 2 shows the emission spectrum of a 0.5 to 1.5 mm grain-sized sample of Brazilian quartz for which the spectrum was recorded out to 40 μ and indicates that spectral data are as accessible in emission around 20 μ as at around 10 μ.

For the observation of infrared emission spectra of extraterrestrial bodies, it is fortuitous that there exist two atmospheric windows which largely coincide with the regions of the spectrum which are of interest. They are the well known and widely utilized 8- to 14-μ window, and another partial window which occurs at 16 to 24 μ. These windows are indicated in Fig. 2. Adel (*2*), in studying the emission from the earth's surface, points out that the energy lost through the 20 μ window may reach values in excess of 30 percent of the loss through the 10-μ region. The absorption in the 16- to 24-μ region is entirely due to water vapor, and it seemed likely that the low moisture content of the air above Flagstaff, Arizona, would make it possible to obtain emission spectra from the moon.

Observations of the emission from the moon through the 8- to 14-μ window have been generally of three types:

1) Spectral scanning of the whole disc during full moon (*3*).

2) Temperature measurements made by tracking across the lunar surface a fixed spectral range (radiometric measurements) during full moon (*4*).

3) Observation of lunar features during rapid cooling at the time of eclipses to observe variations in thermal properties (*5*).

We know of no previous observation of the moon through the 16- to 24-μ window. We selected four lunar features, namely, central Highlands, Serenitatis, Copernicus, and Tycho, and scanned each of these through the 16- to 24-μ atmospheric window.

The observations were made with the

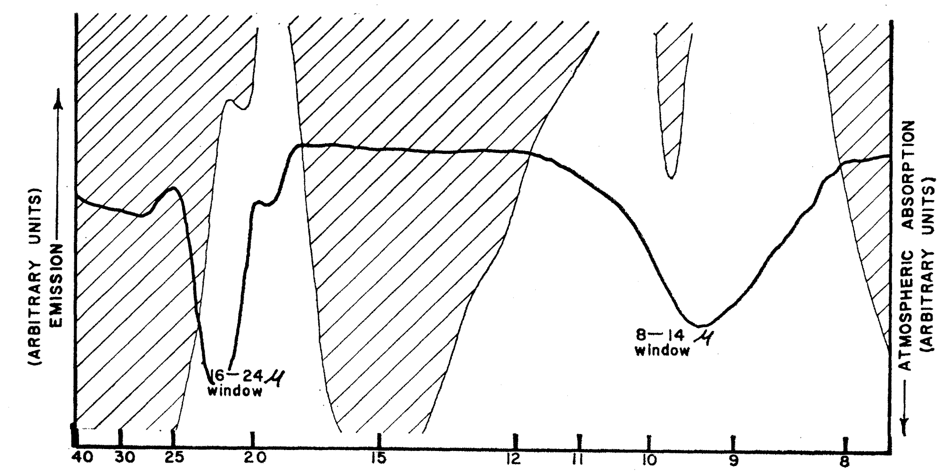

Fig. 2. Emission spectrum of Brazilian quartz with atmospheric absorption spectrum superimposed. The relative intensities of transmission through the 16- to 24-μ window are exaggerated.

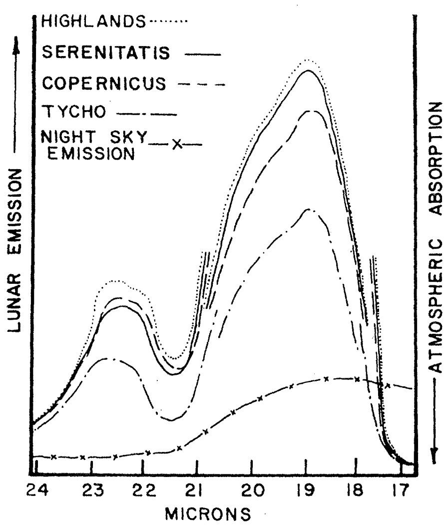

Fig. 3. Emission spectra of four lunar surface features through the 16- to 24-μ window. The amplifier gain was 1.5 between 17 and 24 μ and 2.5 between 21 and 24 μ.

42-inch (107-cm) telescope at Lowell Observatory, Flagstaff, Arizona, on 26 February 1964. Unfortunately, the humidity was unusually high (38 percent in late evening to 33 percent early morning at −5°C and −7°C, respectively) and hence the windows were not as clear as would be expected. A Perkin-Elmer model 98 single-beam spectrometer with KBr prism was modified by constructing an enlarged slit wedge, which allowed the slits to be opened to a maximum of 6 mm, and by using an Eppley Laboratories Golay detector equipped with a KBr window which was fed directly from the exit slit with a 4:1 reducing torroidal mirror. Conversion of the $f/33$ beam from the telescope was effected by using fore optics, constructed by Sinton (*6*), in which a KBr lens was used and the oscillating chopper mirror was replaced by a fixed 2.54-cm, 114-mm mirror.

The spectra recorded through the 16- to 24-μ region are shown in Fig. 3. The curves shown are direct traces, without smoothing, of the continuously recorded emission spectra from four lunar-surface features modified by the atmospheric absorption where the sample size on the moon was approximately 80 × 480 km. The noise level was less than 1 percent and the resolution better than 0.4 μ. Between 17 and 21 μ the spectra were recorded with a gain setting of 1.5, while for those shown between 21 and 24 μ the dynamic range was increased by increasing the gain to 2.5.

If the usual assumption is made that the lunar surface is emitting as a black body, then recorded spectra from various lunar regions should appear as a family of curves representing transmission through the atmosphere from a source in which the temperature had been varied. Subtraction of the atmospheric absorption or one curve from another then yields a set of smooth, almost parallel curves. This is not the case for the present observations (Fig. 3), and the discrepancy between the emissions from Copernicus and Serenitatis is the most apparent. At 19 μ the emission from Serenitatis is stronger than from Copernicus, while at 23.5 μ the relative intensities of emission are reversed. The curves do in fact actually cross.

Such an effect cannot be explained as being due to differences in surface roughness, changes in atmospheric absorption during the observations, or to some peculiar distribution of emitted energy resulting from temperature differentials within one sample area. The surface temperature in one region would have to be predominantly something less than 140°K to produce the type of difference in spectra we observe here. Black-body emission at this temperature would not be detected by our Golay detector, which was operating at about 300°K. Also the Copernicus and Serenitatis spectra were recorded consecutively and repeatedly, so that neither changes in the transmission through the atmosphere nor in instrument performance would be expected to have caused the observed anomalies.

We are, therefore, led to the conclusion that the comparative differences in intensities of the recorded spectra are due to the superimposition of differences in spectral emission from the lunar surface materials upon the absorption of the atmosphere and result from compositional differences between the lunar features examined. What these anomalies are remains to be determined.

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References and Notes

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7. We thank Dr. J. Hall and Lowell Observatory for the use of the 42-inch telescope, Dr. W. M. Sinton for making available his fore optics for our spectrometer, and R. Allen of Arthur D. Little, Inc., for preparation of the polished rock samples used for the reflection spectroscopy.

20 July 1964

Cigarette Smoke: Charcoal Filters Reduce Components That Inhibit Growth of Cultured Human Cells

Abstract. *Water-soluble components of total cigarette smoke inhibit cell growth and protein synthesis by the KB line of human cells. The cytotoxic components were in both the gas phase and the particulate phase of smoke. Conventional filters of cellulose acetate reduced cytotoxicity of the particulate phase in proportion to the weight of particles trapped, that is, they did not alter the specific activity of the particulate phase. Appropriately designed filters containing activated charcoal granules selectively reduced cytotoxic components in cigarette smoke which would have appeared in both phases, although the reduction, as anticipated, occurred to a greater extent in the gas phase.*

A filter containing activated charcoal granules designed to remove gas phase components selectively from cigarette smoke has been used to study the inhibitory effects of cigarette smoke on mammalian ciliary transport activity (*1*). Our present results, another phase of this work, show that the water-soluble components of cigarette smoke condensate inhibit the growth of mammalian cells in culture; this activity is found in both phases (gas and particulate); and the charcoal granule filter reduces activity, particularly by reducing the components in the gas phase. The toxic effects of cigarette smoke, smoke condensates, or components thereof on mammalian cells in culture have been previously investigated by several workers (*2–4*). In one investigation, bubbles of "gases" from cigarettes and other combustion products were passed directly over the surface of cells with resultant "blebbing" and cell death (*5*). Studies of *Paramecium* (*6*) showed some morphological effects as well as lethality due to mainstream smoke.