Final Report
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Observations

Photometric and polarimetric observations of the moon and other objects were obtained in three sessions: in November 1963 and February 1964 with the 82-inch reflector of the McDonald Observatory in West Texas, and in December 1963/January 1964 with the 21-inch reflector of the Lunar and Planetary Laboratory in the Santa Catalina Mountains, north of Tucson. The reductions were greatly facilitated by the use of digitized equipment. Until now, the measurements had been made with registrations on the chart of a Brown recorder, the charts were read, and the results punched on IBM cards for machine computation. The intermediate stage of reading the Brown charts is, however, slow and expensive. I estimate that a 10-day run at the telescope used to cost about $1300 for the hand reductions. This intermediate stage has been eliminated by using a digital voltmeter with associated electronics.

Mie Calculations

Calculations were made on the Mie theory of brightness and polarization predicted for spherical particles with a range of size and refractive index. The calculations have been used on the particles in the surface layer of the moon. They will also be useful in the future for an analysis of interstellar particles in reflection nebulae.

Publication

The results of the observations and of the Mie calculations are presented in a paper of which 25 reprints will be sent to the Office of Grants and Research Contracts, as soon as they are available. The paper actually assembled many observations made in 1956-1964. The Abstract of the paper, submitted to the Astronomical Journal 69, 1964, now follows.

The Wavelength Dependence of Polarization. III. The Lunar Surface*

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Photoelectric photometry and polarimetry were made on various lunar regions with diaphragms about 10 arcseconds in diameter. In addition to UBV a UGI photometric system was used, where I has effective wavelength at 0.94 micron. The color index of lunar regions increases with phase angle α; a typical relation is $B-V = +0.84 + 0.0017\,|\alpha|$. Brightness - phase relations all show a non-linear surge close to zero phase; this "opposition effect" may be as much as a factor of 2 brightness increase from ±5° to 0°.0 phase. If so, the full moon has $\bar{V} = -13.35$ mag ±0.06 (p.e.), and the geometric albedo at 5400 Å is 21% with the maria having 13% and the continents 27%; the uncertainty is mostly due to luminescence effects.

Luminescence was detected in the photometry and it was independently confirmed by the polarimetry. In 1956/59 the lunar surface was 10 - 20% brighter than in 1963 November/1964 January. The effect was fairly constant from day to day.

Polarization - phase curves with a filter at 0.54 micron were found similar to those of Lyot, while at 0.36 micron the polarization generally is greater and at 0.94 micron smaller. Gradual rotation of the polarization position angle, as reported in the literature, was not found; to within ±3° precision, the electric vector maximum is either perpendicular to the plane of scattering, or lies in that plane.

The photometry is closely reproduced by the theoretical photometric functions of Hapke (J. Geophys. Res. 68, 4571, 1963) that had been derived for a tenuous surface texture. The texture is remarkably uniform over the lunar globe, and it is similar to that of the asteroids. The polarizations and albedoes appear consistent with Fresnel's laws of reflection, and refractive index $\underline{m} \approx 1.34-0.02\underline{i}$ was found for the texture.

The lunar surface appears covered with a thin, about 0.1 mm, cloud of particles that have radius $\underline{a} \approx 0.8$ microns, and separation of about 10 microns. They presumably are accreted interplanetary particles. They are ionized and their charges, of the order of 10^{-8} esu, keep them separated and suspended, while partial recombination causes the observed luminescence. It appears that this surface cloud explains all photometric and polarimetric observations on the moon and asteroids.

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