A QUANTITATIVE EVALUATION OF THE UNIFORMITY OF THE LIGHT SCATTERING PROPERTIES OF THE LUNAR SURFACE

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Abstract. A catalogue was compiled in the author's previous paper (Jones, 1969) of the relative brightness of 199 lunar features as observed at phase angles of 2°.1, 17°.5, 32°.5, 46°.2, 59°.4 and 72°.1 before full Moon, in the wavelength interval 5500 to 7000 Å. The present paper is concerned with an interpretation of this data in terms of the uniformity of the photometric function of the lunar surface. If due account is taken of the effect of second order scattering it is found that all the survey points studied scatter light according to the same photometric function independent of the type of terrain on which they are located.

1. Introduction

The optical scattering properties of the lunar surface are determined primarily by the effects of self shadowing within a surface microstructure that is rough and porous on a millimetre - centimetre scale but apparently smooth on a scale of tens of centimetres and above. Any earth based investigation into the uniformity of these properties over the visible lunar hemisphere should thus provide invaluable information on the microstructural uniformity of the lunar surface layer itself. Because of the orbital constraints in the Earth-Moon-Sun system, the scattering indicatrices of individual surface elements cannot be constructed from terrestrially based observations. However, because of the special nature of the lunar scattering law and its inherent uniformity over the lunar surface, it is possible to compare the optical scattering properties of individual surface elements with those of the mean lunar surface. The experimental data required for such a comparative survey was presented in the form of a Photometric Catalogue in the author's earlier paper where the relative brightnesses of 199 lunar surface areas were tabulated for the wavelength interval 5500 to 7000 Å at phase angles of 2°.1, 17°.5, 32°.5, 46°.2, 59°.4 and 72°.1 before full Moon (see Jones (1969)). At each phase angle the brightness values were measured at a surface resolution of 3 km x 3 km on the projected lunar disc and were expressed relative to the mean brightness of all the points observed at that phase. No attempt was made to determine the factors necessary for comparing the brightness values at different phases. The present paper deals with the author's interpretation of the data contained in the Photometric Catalogue in terms of the uniformity of the optical scattering properties of the lunar surface layer over its terrestrially visible hemisphere.

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2. A First Order Evaluation of the Catalogue Data in Terms of Single Scattering

To a good approximation the optical scattering properties of the lunar surface layer are such that:

(a) The lunar photometric function \( \phi \) is fully described in terms of phase angle \( \alpha \), and brightness longitude \( \lambda^1 \).

(b) The observed brightness, \( B \), of any surface element is dominated by singly scattered rays such that

\[
B = A \phi(\alpha, \lambda^1) = Af_1(\alpha)f_2(\alpha, \lambda^1) \quad \text{(Hapke, 1963)}
\]

where \( f_1(\alpha) \) describes the effect on scattering of the surface microstructure and its component grains, and \( f_2(\alpha, \lambda^1) \) describes the effect of the surface geometry of a smooth or gently undulating surface whose microsurface is porous. \( 'A' \) denotes the albedo of the surface element measured at full Moon. Except in the close proximity of the limb or terminator, \( f_2(\alpha, \lambda^1) \) may be expected to vary little over the surface so that the uniformity of the microstructure term, \( f_1(\alpha) \), should be readily measurable from constant phase plots of first order albedo corrected brightness, \( B/A \), as a function of the brightness longitude, \( \lambda^1 \). If a mean curve is fitted to each plot to represent the dependence of \( B/A \) on \( \lambda^1 \) for the mean lunar surface, a measure of the uniformity of \( f_1(\alpha) \) in terms of a single scatter model is obtained by studying the deviations of the \( B/A \) values of individual surface elements from the mean surface curves.

The relative brightness values observed at a phase angle of \( 2^\circ.1 \) were taken to represent the relative albedo of each surface area observed in the Photometric Catalogue and first order albedo normalized factors \( \frac{1}{B_a} \) were determined for each survey point observed at each phase angle such that

\[
\frac{1}{B_a} = 100 \frac{B_a}{B_{2^\circ.1}},
\]

with \( B_a \) representing the observed relative brightness of the surface element at a phase angle \( \alpha \) as tabulated in the Catalogue. These values were plotted at each phase angle as a function of selenographic longitude, \( \lambda \). In the absence of local surface slopes, the sole effect of plotting against \( \lambda \) instead of \( \lambda^1 \) at a given phase is to shift the brightness versus brightness longitude curve along the latter axis by a distance equal to the libration in longitude. The resultant first order survey diagrams are shown in Figure 1.

It is immediately apparent from Figure 1 that a significant scatter of data points will result about any mean curve fitted to represent the dependence of \( \frac{1}{B_a} \) on \( \lambda \) for the mean lunar surface at any given phase. However, there are strong indications from the similarity in the scatter pattern of each plot that the data scatter is not random but rather due to variations, at least in terms of the single scatter model, in the light scattering properties of the lunar surface.

As reliable mean surface curves could not be fitted to the first order survey diagrams because of the scatter in the data, a preliminary analysis was conducted using a simple curve fitting programme. For each phase angle a least-squares parabolic curve fit was