BACKSCATTER MEASUREMENTS AND IMPACTED SURFACES.

Milo Wolff,
International Technology Associates, Inc. 7303 N. Marina Pacifica Drive,
Long Beach, CA 90803.

Summary

Light reflected from asteroids and moons depends on the properties of the fluffy regolith created by micrometeoroid impacts. It is a purpose of this paper to show that the geometric structure of the regolith and some of its optical properties are revealed by measurement of the photometric backscatter peak height and width.

Other measurables, including polarimetric P(min), phase angle of P(min), inversion point, polarimetric slope, and the reflection spectra possess characterisitcs dependent on the backscatter and may be more easily and accurately interpreted if concurrent intensity measurements, especially the backscatter peak, are made with them.

The CSM taxonomy of (2) for classifying asteroids is interpreted in terms of the light-reflection processes implied by the coordinates of the CSM diagrams. The C, S, and R types are tentatively identified as members of a normal sequence of impacted surfaces, whereas the M and E probably have abnormally structured surfaces.

It is concluded that the wealth of data on polarization, for example, (2, 3, 6), and on reflectance spectra (4), could be further usefully applied by addition of backscatter measurements. Tom Gehrels wrote (p. 7) in "Planets, Stars and Nebule Studied with Photo Polarimetry", the word photo-polarimetry... is to convey the conviction that the observations and analyses of photo-polarimetry and polarimetry should be combined.

Computing Light Behavior

A method of computing (5) light reflected from a pitted particulate surface is to use

$$\text{Reflected light} = \left[I_o \left(f_1 \frac{\bar{X} + \bar{Y}}{2} \right) + f_{21}\left(\frac{\bar{X}}{2}\right) + f_{22}\left(\frac{\bar{Y}}{2}\right) + f_3 \right]$$

where, $\bar{X}$ and $\bar{Y}$ are $\parallel$ and $\perp$ Fresnel coefficients for single reflection as a function of phase angle and complex refraction, and $\bar{X}_2$ and $\bar{Y}_2$ are $\parallel$ and $\perp$ Fresnel coefficients for double reflection (a matrix). The modifiers f_1, f_{21}, f_{22} and f_3 are functions of the phase angle and modulate the light components in accordance with the surface structure.

The function f_3 accounts for the non-polarized diffuse light due to triple and higher order reflection, refraction, point scattering and other random processes. The largest part of f_3 begins with refraction into the surface particles and therefore is responsible for "reflection" spectra.

Physical Laws Combined with Estimates

No one can exactly calculate the properties of a jagged meterorite-impacted surface! In places, some physical laws can be applied, some geometry of pits and shadows can be used, but when these are exhausted, educated guessing is needed to formulate f_1, f_{21}, f_{22} and f_3. An important educational aid will be back-scatter measurements.

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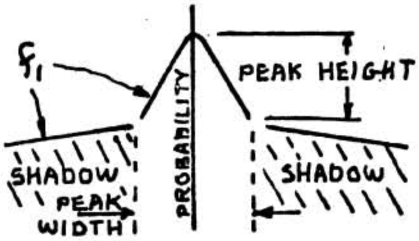
The function f_1 would look something like Fig. 1 with the peak width and height conforming to measured backscatter.

Figure 1. The function f_1 has two parts : a back-scatter portion accounting for light reflected from pit bottoms near opposition, plus, a smooth portion to account for light not captured by pits at larger phase angles.



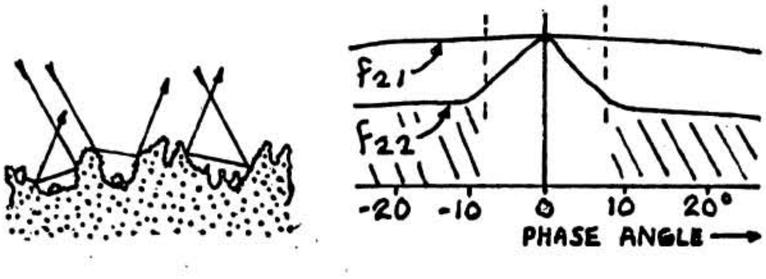
Unique Double Reflection Properties of Pits

The functions f_{21} and f_{22} are determined by the pitted regolith which strongly enhances the probability of double reflections as shown in Fig. 2. Computer modeling used to match lunar measurements and the model leads to the estimate that the ratio of double reflections to single reflections is ten times larger for a pitted surface than for a random particle cloud! The ragged surface both attenuates singles and enhances the doubles.

Particle-filled pits have another property contrasting with particle clouds in that the particle backsides (away from the light source) are back-lighted by reflection from different particle frontsides. This is the light which contributes to negative polarization, as shown in the classic experiment by Dollfus (1956) in which widely separated grains of poured sand showed no negative polarization whereas close-packed grains did.

The properties of the backscatter function can tell us a lot about f_{21} and f_{22} which look like figure 2A and 2B. The f_{21} function is the probability of double reflections into left or right quadrants after the first reflection. It varies smoothly with phase-angle and is not much affected by shadows because the path is out of the plane of vision. The function f_{22} is strongly affected by shadowing as the phase angle moves away from oppostion. Forward rays are attenuated and f_{22} drops to about 50% amplitude and results in a net negative polarization.

Figure 2. The surface pits enhance the probability of double reflections, except those with a forward-going intermediate path, which are attenuated at larger phase angles by f_{22}.



One often reads, "Multiple-scattering becomes negligible in very dark surfaces". This is true for refracted rays, but double reflection intensity <u>increases</u> because of the larger imaginary component of the refractive index. Indeed, for a dark type C asteroid, the light due to doubles may be as much as 20% to 40% of the total.

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Relationship of the Negative Polarization Branch

The theory of (5) predicts that the negative branch shape depends on the competing strengths of polarization due to singles, left-right doubles, and forward-backward doubles, which are determined by the particle-filled pitted surface and revealed by back-scattering. Because of the scarcity of measurements of the backscatter peak together with polarization as a function of phase angle, there is no firm confirmation of this prediction. If simultaneious measurements were available for a sample of moons and asteroids, improved knowledge of double reflections would lead to improved knowledge of surface structure, index of refraction, and the proportion of rays which are involved in absorption spectra.

Distinguishing Asteroids

The CSM taxonomy of (1) can be joined with thie theory by interpreting the axes of the CSM diagrams in terms of the types of reflected light, as in Fig. 3. One can then postulate a normal albedo sequence, as shown, which is defined as a path connecting the C, S, and R domains in a CSM diagram which uses P(min) or albedo as one coordinate.

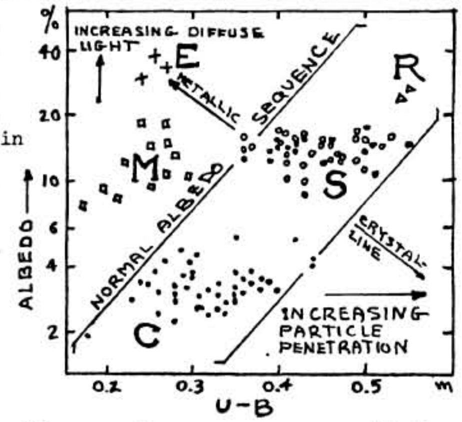

Figure 3. (after Zellner & Bowell). The CSM taxonomy contains a diagonal path describing a normal micrometeoroid impacted surface. The normal sequence represents a physical variable of the surface, i.e. the product of mean grain size and grain absorbtivity which normally increases towards UV colors. Increasing absorbtion causes less diffuse light, more singles light, more doubles light, and more polarization. This therefore suggests that the diagram has meaning in terms of light reflection processes taking place in the surface material. These processes have been added to the diagram.

The failure of type E and M objects to lie on the sequence could be explained by:

1. The absorptivity of the surface material changes little with wavelength.

2. The surface does not possess a typical impacted pitted particulate surface.

3. The surface is very metallic (high absorptivity) and thus very reflective.

If either 2) or 3) are true, then 4) probably follows. Measurements of the backscatter peak might verify or exclude 2) or 3).

The slope-albedo rule should be used cautiously for objects not on the normal albedo sequence since the presumed surface condition may not be there. However, opposition peak measurements could be used for an estimate of the singles and doubles to derive suitable new constants for the slope-albedo rule.

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