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Laboratory simulation of light scattering from regolith analogue: Effect of porosity and particle size

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Abstract. The surfaces of most of the atmosphereless solar system bodies are referred to as regolith or layers of usually loosely connected fragmentary debris, produced by meteorite impacts. Measurement of light scattered from such surfaces provide information about the composition and structure of the surface. In the present work, the effect of porosity and particle size, on reflectance is studied for regolith like samples. For modelling the experimental data Hapke 2008 is used and found to be in good agreement with laboratory data. From the present study, it can be concluded that the physical properties of a regolith, such as porosity, particle size etc are effectively represented by albedo.

Keywords. photometry, regolith, asteroid, scattering

1. Introduction

The surfaces of most atmosphere less solar system bodies are referred to as regoliths (containing particles sub micron to few hundred microns in sizes) which are layers of usually loosely connected fragmentary debris, produced by meteoritic impacts. This regolith layer can be few meters in thickness. Light scattering is a useful tool to infer the physical properties of such surfaces. The light reflected from such surfaces carries information about the particle size, porosity, composition etc of the surface. Laboratory photometric and polarimetric studies of regolith analogous sample provide a unique opportunity to enhance our knowledge of small bodies in the solar system.

2. Experimental setup

The laboratory simulation was performed with the help of a gonio-photometric device at the Department of Physics, Assam University, Silchar, India (c.f. Kar *et al.* 2016). It consists of two metal arms having a common horizontal axis of rotation. The two arms can be rotated by ±90° from the zenith direction and there is a sample tray at the center which can tilt up to 20° perpendicular to the plane of arms. A 632 nm He-Ne laser source and the CCD detector are used. For imaging a thick lens [converging] is mounted in front of the CCD camera. The tilt angle of the sample container was kept fixed at 0° for all the data set. The reflectance r (i,e,g) was calibrated by using a standard lambertian surface of BaSO4, at a condition i=0° , e= 45° , g=45° where i is the angle of incidence, e is angle of emergence and g is the phase angle. The fluctuation of laser introduces uncertainty, which has been found to be less than 2%.

The porosity P of the powder samples was calculated by using the relation [Sakai, Nakamura 2005].

$$P = 1 - m/\rho v \tag{2.1}$$

Table 1. Estimating Hapke's Parameter for Brown corundum with particle sizes 22, 35 and 88 micron. All the samples are having same volume with sample container knocked once.

Sample	D [μm]	P	r(i,e,g)	ω_1	H	r(i,e,g)	ω_2	H
	22	0.69	0.103	0.85	1.432	0.104	0.86	1.445
Brown corudum	35	0.54	0.064	0.63	1.210	0.064	0.61	1.200
	88	0.47	0.049	0.49	1.136	0.049	0.47	1.132

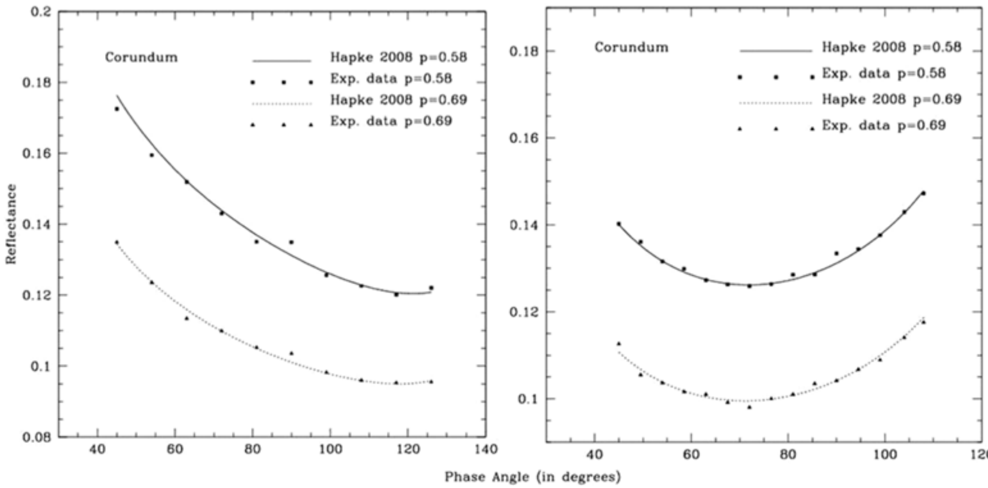

Figure 1. First set of experiment (left panel) includes variation of both incident (i) and emergent(e) angle at a condition $i = e$. In the second set (right panel), incident angle is fixed at 45° and emergent angle varies from 0° to 63°

where m is the total mass of the particles in the sample tray, ρ is the bulk density of the powdery material, and V is the volume of the sample tray.

3. Modelling of experimental data

According to Hapke (2008), the bidirectional reflectance from particulate medium containing particles of size greater than wavelength is given by

$$r(i,e,g) = K\left(\frac{w}{4\pi}\right)\left(\frac{\mu_o}{\mu+\mu_o}\right)\{p(g) + H(\mu_o)H(\mu) - 1\} \tag{3.1}$$

where

$$K = \frac{-\ln(1 - 1.209\phi^{\frac{2}{3}})}{1.209\phi^{\frac{2}{3}}}, \tag{3.2}$$

Here ω is the single-scattering albedo; μ_o and μ are respectively the cosine of incident and emergence angles, g is the phase angle.

$$p(g) = \frac{1-\xi^2}{(1 + 2\xi\cos g + \xi^2)^{\frac{3}{2}}} \tag{3.3}$$

The quantity ξ in the HG function is the asymmetry factor. The term H(x/K), contributes for multiple scattering expressed as

$$H(x/K) = \frac{1 + \frac{2x}{K}}{1 + \frac{2\gamma x}{K}}, \tag{3.4}$$

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In the present modelling, we have taken ω as a free fitting parameter. We used chi square minimisation technique to fit the experimental data with Hapke model (Table 1). The best fitted model curves with experimental data are shown in Figure 1.

4. Conclusion

1. Porosity, a microscopic property of any regolith sample, seems to have a distinguishable effect on reflectance.

2. The dependence of reflectance on porosity, as observed through our experiment, have been also theoretically generated using Hapke (2008) model. These two sets of values are found to be in good agreement.

3. From the phase curves, it can be concluded that the physical properties of a regolith surface, such as porosity, dimensions of the particle are effectively represented by albedo. Moreover the dimension of particles and bulk porosity appear to be interrelated, since by changing the size of the particles one can change the bulk porosity of the sample.

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