REFLECTANCE AND POLARIZATION PHASE CURVE MEASUREMENTS OF CANDIDATE PLANETARY REGOLITH MATERIALS

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Introduction: The reflectance and polarization of light reflected from solar system objects contains important information regarding the chemical and textural properties of the regolith. Remote sensing data can be compared to laboratory angular scattering measurements of candidate materials to constrain surface properties of planets and small bodies. We present Goniometric Photopolarimeter (GPP) measurements of reflectance and polarization with respect to phase angle of media that simulate planetary surfaces.

Our GPP employs the Helmholtz Reciprocity Principle - the incident light is linearly polarized - the intensity of the reflected component is measured[1,2]. Instruments of this type are generally classified as a "polarization-sensitive well-collimated radiometers," and the Al_2O_3 samples are classified as "discrete random media[3]." These lab measurements are physically equivalent to remote sensing measurements of planetary regoliths of atmosphereless planets and small bodies.

We report reflectance and polarization phase curves for a suite of 13 well sorted, highly reflective particulates (Al_2O_3). These materials exhibit an increase in circular polarization ratio with decreasing phase angle consistent with coherent backscattering (CB) of photons in the regolith[4]. Shkuratov et al. report that the polarization properties of these particulate media are also consistent with the CB enhancement process[5].

Table 1.
Sizes of Al_2O_3 particulate samples used in this study.

Particle Size (μm)	void space (%)	Particles per cm³
0.1	97.68	4.43 E+13
0.5	96.30	5.66 E+11
1.0	95.50	8.59 E+10
1.2	94.94	5.60 E+10
1.5	95.81	2.37 E+10
2.1	84.60	3.18 E+10
3.2	83.10	9.85 E+09
4.0	82.21	5.31 E+09
5.75	81.74	1.83 E+09
7.1	76.83	1.24 E+09
12.14	75.41	2.62 E+08
22.75	70.70	4.75 E+07
30.09	65.85	2.39 E+07

Reflectance Phase Curves: The reflectance phase curves, normalized at 5^0, are shown in Fig 1. The curves are displaced upward in increments of 0.1 beginning with the largest particle size shown at the bottom. Despite being the same material chemically these particles manifest differing morphology. The particles smaller than 1.5 µm are equant in shape; while those larger than 2.1 µm are platlet shaped[6]. We suggest this, along with void space, has great impact on the character of reflectance and polarization phase curves particularly at or near extremely small phase angles.

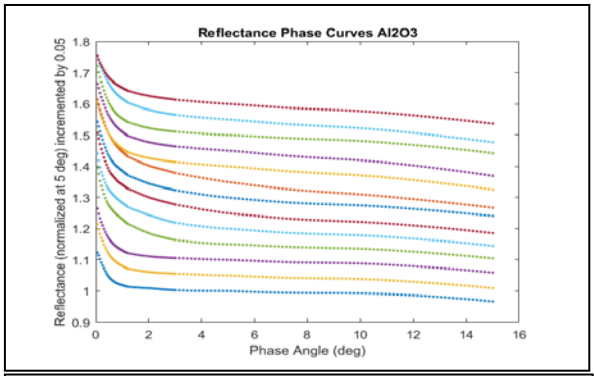

Fig. 1. Phase curves of the Al_2O_3 samples. 30.09 µm diameter (bottom) is normalized at 5^o, decreasing particle sizes are incremented by 0.05 in normalized 5^o reflectance. They are (proceeding upward) 22.75, 12.14, 7.1, 5.75, 4.0, 3.2, 2.1, 1.5, 1.2, 1.0, 0.5, 0.1 µm respectively. The smaller particles are equant; the larger ones are platlet shaped.The pronounced change in the character of the phase curves of particles <=1.5 and those >= 2.1 µm suggests particle shape and void space are significant.

For each particle size we fitted a straight line to the phase curve data from 5-12^o. A typical fit for the 1.0 µm size is shown in Fig. 2. The straight line was extrapopated to 0^o, the size of the opposition surge and the area under the phase curve were calculated for each particle size. The size of the opposition peak and the area between the phase curve and the extrapolated straight line from 5-12^o clearly depends on particle size and void space. It is largest for particle sizes that approximate the wavelength of the incident light (λ=0.635µm). This is where CB of the incident photions is maximim. It decreases with decreasing particle size for sizes < 1 µm and decreases with increasing particle size for sizes >= 1 µm.

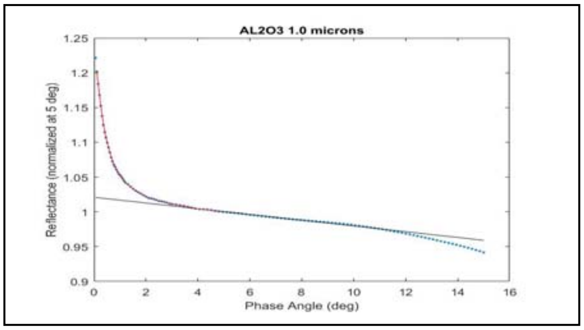

Fig.2. Phase curve for 1.0 µm Al_2O_3 particles. A straight line is fitted to the data from 5-12°. This is extrapolated to 0°.

Polarization Phase Curves: The polarization phase curves for the particle sizes > 2.1 µm have no polarization phase angle dependence. The particle sizes that are <=1.5 µm exhibit a pronounced polarization vs. phase angle relationship. This is evident in fig 3. Polarization decreases with decreasing particle size.

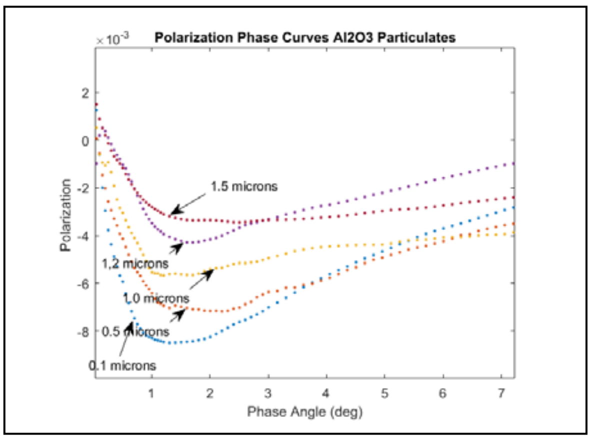

Fig. 3. Polarization phase curves of the Al_2O_3 samples

In 2002, we measured the polarization phase curves of these same Al_2O_3 materials using a GPP at the Karazin University in Kharkiv, Ukraine[5]. The Karazin University GPP had been previously calibrated to the JPL GPP and the reflectance results from both instruments were consistent when measuring like materials. Similar results have been reported by many reputable groups[7-9].

Relevance to the Regoliths of the Galilean Satellites

In 1997 Rosenbush et al, reported polarization phase curves of Europa that were unlike those reported for many other solar system objects[10]. In subsequent reports they find that Europa, Ganymede and Io, the high albedo Galilean satellites, have polarization phase curves with a pronounced asymmetric minimum at about 0.5°. Our results show a simiar effect as measured in the laboratory for Al_2O_3 particles.

If we assume the Al_2O_3 particulates simulate the scattering properties of a particulate water ice surface of Europa then we are able to approximately replicate the polarization phase curve of Europa assuming an extremely fine grained and highly porous regolith with void space exceeding 90% (see table 1).

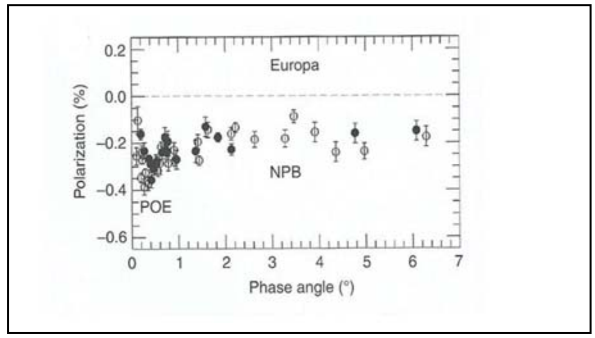

Fig 4. Polarization phase curve of Europa reported by Rosenbush et al.

Conclusion: In laboratory measurements of the angular scattering properties of particulate materials comparable in size to the wavelength of the incident light, the polarization decreases as particle size decreases, and the polarization minimum is observed as smaller phase angles. Comparison of laboratory polarization phase curves of fine grained particulate materials with the polarization phase curves of Europa reported by groundbased astronomical observers suggests that sunlight is scattered from Europa by a surface that is very fine grained and extremely porous, perhaps as high as 90%.

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