A STUDY OF OPPOSITION PHASE CURVE IN LOW ALBEDO MEDIA R. M. Nelson[1]. B. W. Hapke[2], W. D. Smythe[1], A. S. Hale[1], J. L. Piatek[2], [1] Jet Propulsion Laboratory, MS 183-501, 4800 Oak Grove Drive, Pasadena CA 91109, Robert.M.Nelson@jpl.nasa.gov, [2]Department of Geology and Planetary Science, 321 OEH, University of Pittsburgh, Pittsburgh PA 15260.

Introduction: The Opposition Effect, the pronounced non-linear intensity increase in the reflectance phase curve with decreasing phase angle, θ, has long been observed in solar system bodies and in laboratory investigations of the angular scattering properties of particulate media[1]. The size and shape of the phase curve, and the change in linear polarization with θ, have been related to the physical properties of planetary regolith scattering materials [e.g. 2,3]. Near zero degrees the increase in reflectance with decreasing phase angle has been attributed to two distinct processes. The first is the elimination of shadows cast between the regolith grains as the phase angle decreases. This is called the shadow hiding opposition effect (SHOE)[4]. The second is coherent constructive interference between rays of light traveling along identical but opposite paths in multiply scattering media. This is called the coherent backscattering opposition effect (CBOE). [5,6,7,8].

Measurements of the angular scattering properties of planetary regolith materials and particulate ensembles simulating planetary regoliths provide useful tests of the theoretical models [9,10,11,12]. These investigations of regolith simulants form a very important link with laboratory studies of CBOE for model development and verification [e.g. 13,14, 15].

We report the results of an investigation into the opposition surge of low albedo particulate materials of varying particle size and packing density. We had previously reported that for a material of relatively low reflectance (~13%) the circular polarization ratio exhibits increasing slope with decreasing phase angle down to the angular limit of our measurement [16]. This is unusual because it suggests that there is significant multiple scattering in low albedo materials. Therefore, we studied materials with reflectance of less than 10% to investigate further the contribution of multiple scattering to the reflectance phase curves in low albedo metarials. We find that these very low albedo materials exhibit nearly constant circular polarization ratio with decreasing phase angle consistent with SHOE being the overwhelming contributitor to the phase curve.

The Experiment: The measurements were made on the long arm goniometer at NASA's Jet Propulsion Laboratory . A detailed description of the experimental procedure is found in our earlier publications [12]. The phase angle studied varied from 0.05 to 5°. Four particulate samples of silicon carbide, boron carbide, ferric oxide and cobalt oxide were presented with linearly and circularly polarized coherent light from a laser of wavelength 0.633 μm. The samples differed in reflectance from 13% to 1.6 %. They were uncompressed (~75% void space). The reflectance of each sample measured at 5° phase angle relative to Spectralon™ was, 13%, 5%, 2.3% and 1.7% for the SiC and B_4C, Fe_3O_4 and Co_2O_3 respectively. The samples were presented with light that was polarized in and perpendicular to the scattering plane. A quarter wave plate was inserted into the optical train at appropriate places to permit the samples to be presented with both senses of circular polarization. The scattered beam was

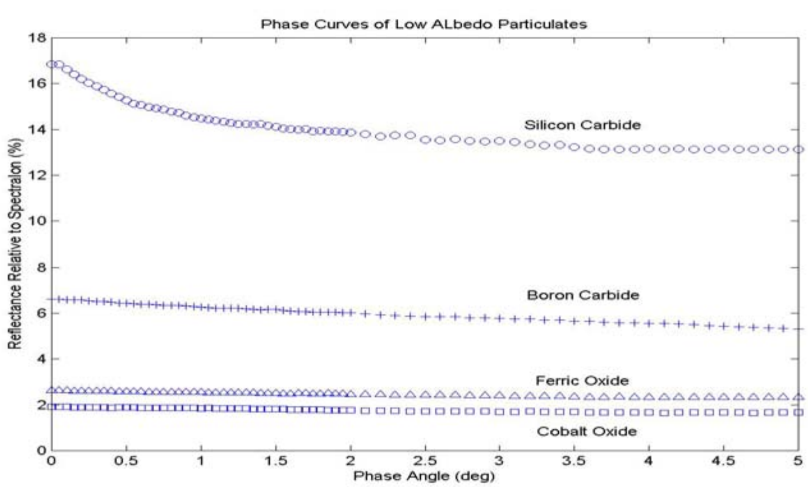

Figure 1. The phase curves of SiC, B_4C, Fe_3O_4, and Co_2O_3 powders.

analyzed in both senses of linear and circular polarization. In this study we combined the data from all of the polarization configurations. We show these as integrated phase curves.

The Results: The integrated phase curves are shown in Figure 1. The phase curves all exhibit an increase in reflectance as phase angle decreases. Of particular relevance to this research is the change in the phase curve as θ approaches 0^o. From 5 to 0^o SiC exhibits a non-linear increase in reflectance compared to the more absorbing media. Figure 2 shows the change in circular polarization ratio with phase angle for the same suite of materials. We have previously reported experimental results which show that an increase in circular polarization ratio with decreasing phase angle can only be caused by the existence of significant multiple scattering in the medium consistent with CBOE [10,12].

Discussion: We have previously shown that significant multiple scattering is observed in materials of high reflectance (70-90%) [12] We found the result for SiC to be unusual given that is it so much more absorbing. However, when the reflectance of the material decreases still further (below (10%) the contribution of multiply scattered light to the reflectance phase curve diminishes significantly. This causes the phase curve to become nearly linear as in the case of B_4C, Fe_3O_4 and Co_2O_3 shown in Figure 1.

Conclusion: We find a significant contribution of multiply scattered radiation in the reflectance phase curve of materials of fairly low albedo even for some materials as with reflectance as low as 13%. The contribution of multiple scattering only becomes insignificant (although still measurable) when the reflectance approaches 5%.

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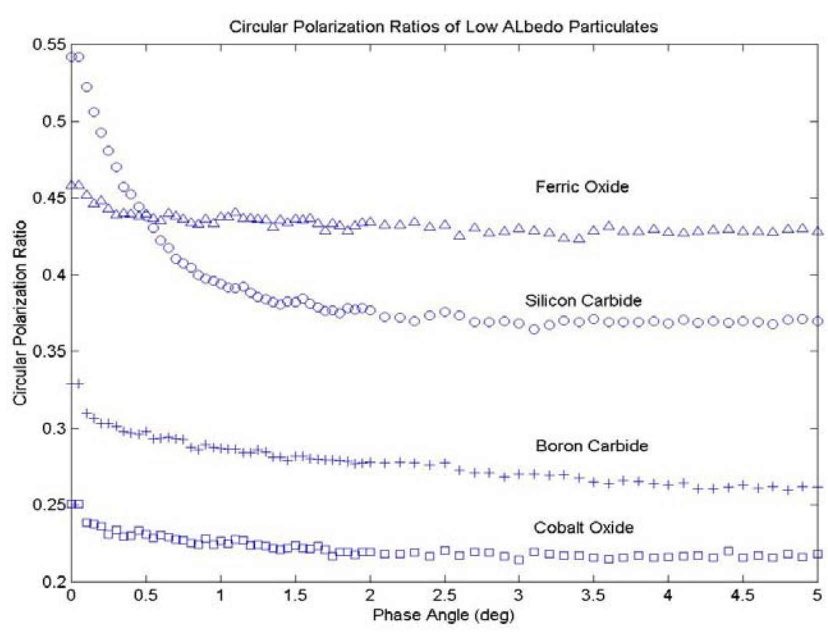

Figure 2. Circular Polarization Ratio of the materials with phase curve shown in Figure 1.