STUDIES OF THE OPPOSITION EFFECT AND NEGATIVE POLARIZATION WITH THE JPL PHOTOPOLARIMETERS; B. Hapke, U. of Pittsburgh; R. Nelson, W. Smythe, L. Horn, V. Gharakanian and P. Herrera, JPL.

A series of measurements of particulate materials are elucidating the nature of the opposition effect (OE) and negative branch of polarization (NP) commonly exhibited by surfaces of bodies in the solar system. Both shadow-hiding (SHOE) and coherent backscatter (CBOE) opposition effects have been observed in our materials. However, the strong, broad CBOE’s and well-developed negative polarizations that are characteristic of planetary regoliths seem to require abundant particles of size \( D \sim \lambda \) in regoliths of intermediate albedos.

This is a progress report summarizing our continuing studies of the light scattering properties of particulate media using the JPL long-arm and short-arm photopolarimeters. These instruments can illuminate samples in both linearly and circularly polarized light from a He-Ne laser (\( \lambda = 0.623 \, \mu m \)) and measure the reflectances in the same and opposite polarizations over a range of phase angles \( \phi = 0.2^\circ-70^\circ \). Circular polarization reflectances are necessary in order to be able to distinguish CBOE from SHOE [1]. Previous studies showed that the opposition effect of the moon is caused by CBOE, rather than SHOE, as was long believed [2]. Our results to date may be summarized as follows.

1. Small (\(<1\,\mu m\)), low albedo (\(<0.01\)) particles: no OE or NP.
2. Large (\(>25\,\mu m\)), low albedo (\(<0.01\)) particles: broad (\(<25^\circ\)) SHOE peak, but no CBOE or NP.
3. Both large and small particles of high albedo (\(>1.00\)): modest CBOE of width \( \sim 5^\circ \) and very broad NP \( \sim 60^\circ \) wide.
4. Intermediate albedo (\(<0.05-0.3\)) powders, either mixtures containing small, high albedo particles or pure substances made up of small particles, including both insulators and metals: strong, broad CBOE and NP \( \sim 1\% \) deep and \( 25^\circ \) wide. These materials exhibit the strongest OE’s that we have observed and their properties are very similar to those of the lunar regolith.
5. Over a range in \( D \sim 0.2-4\,\lambda \), there is no strong dependence of OE or NP on particle size or porosity, probably because when \( D < \lambda \), the waves average over \( \lambda \)-sized clumps.

Our conclusions are as follows.

1. The OE’s and NP’s that are characteristic of planetary regoliths require abundant small particles (\(<10\,\lambda\)) and have albedos such that second order, but not higher order scatterings, are important in their reflectances.
2. The CBOE peaks are consistent to first order with predictions of theoretical models [3,4]. However, there are are number of major discrepancies. In particular, these models predict that the height of the CBOE peak should increase with increasing albedo and that, for particles with \( D \sim \lambda \) the width should decrease with increasing porosity and decreasing \( D \), none of which are observed in our materials.
3. The NP and large circular polarization ratios exhibited by
high albedo materials at large phase angles can be explained by the forward scattered light that is transmitted through the particles, which tends to be negatively polarized and preserve helicity.

(4.) The NP at $g \sim 0-25^\circ$ remains a major puzzle:

(a.) The materials that exhibit a SHOE peak have no NP, showing that the NP is not caused by shadow-hiding [5].

(b.) The NP branch is much wider than the CBOE peak and occurs in the range where the circular polarization ratio is decreasing, rather than increasing, with decreasing phase angle, suggesting that NP is a separate phenomenon from coherent backscatter [6,7].

(c.) However, we have observed planetary-type NP only in those materials that also exhibit CBOE, that is, those containing abundant small particles, which may be either transparent or opaque, of intermediate albedo.

(d.) These observations suggest that the characteristic planetary NP probably involves coherent effects primarily in second order scattered light reflected from the surfaces of the particles of the medium.

REFERENCES: