## *4.5. Light Scattering by Particles and Particulate Surfaces*

*Yu. G. Shkuratov, E. S. Zubko, V. A. Psarev, A. A. Ovcharenko*

We present here results from photometric and polarimetric measurements of laboratory samples (that simulate the structure of planetary regoliths) to DDA and T-matrix simulations of light scattering by small particles with various shapes.

1. Various models have been used to simulate non-spherical dust particles occuring in nature. We use the Discrete Dipole Approximation (DDA) technique exploiting our well-tested DDA code. According to the DDA approach a particle is represented by an array of dipoles densely filling the particle volume. Then the integral equation rigorously describing light scattering by such an array is converted into a system of linear algebraic equations. We solve this system by the method of conjugate gradient using the fast Fourier transformation. Figure 26 shows examples of light scattering agglomerated particles. Actually only the DDA technique allows one to compute scattering properties of such debris particles. Intensity and linear polarization degree are given in Fig. 27 as functions of the phase angle and size parameter $x = 2\pi r/\lambda$ ($r$ and $\lambda$ are the radius of the circumscribed sphere and wavelength, respectively) for agglomerated debris particles. Panels (a)–(c) correspond to the following refractive indecies: $m = 1.5 + 0.1i$, (organic), $m = 1.6 + 0.0005i$, (silicate), $m = 1.31 + 0i$ (icy materials). Calculations made for different refractive index, clearly manifes the evolution of the negative and positive polarization branches with change of the size parameter.

Figure 26. Example of irregular agglomerated debris particle

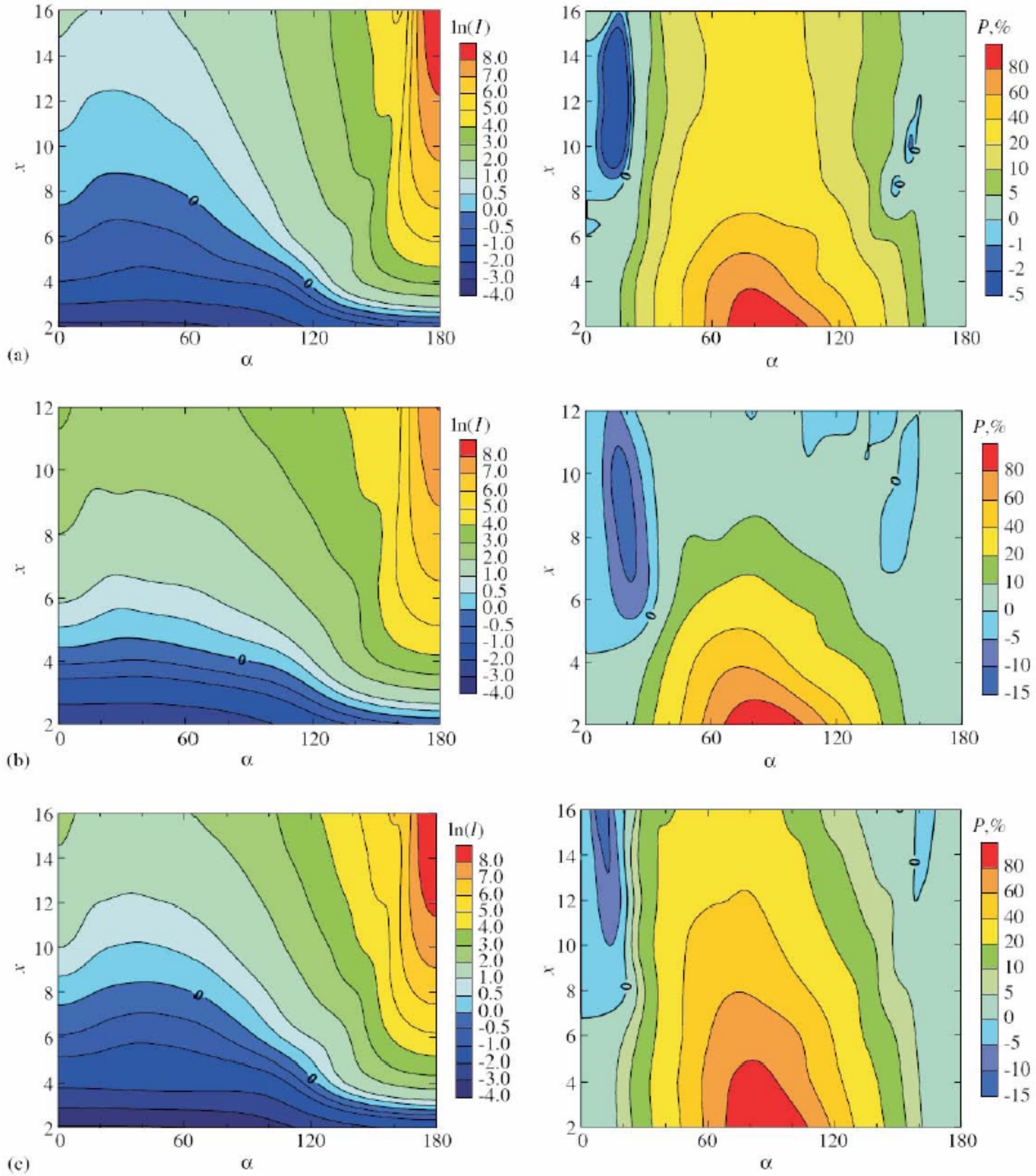


Figure 27. The maps of intensity and degree of linear polarization as a function of the phase angle and size parameter for agglomerated debris particles. Panels (a)–(c) correspond to organic, silicate, icy materials

2. The laboratory studies of structure simulants of planetary regolith are carried out with three instruments operating at small phase angle ranges covering 0.008 – 1.5° (laser photometer) and 0.2 – 17° (lamp photometer/polarimeter) and wide phase angle range 2 –

150° (lamp photometer/polarimeter). The last two instruments allow measurements at wavelengths of 0.63 and 0.45 μm with unpolarized incident light. Note that the phase angle range < 2° is very poorly studied. One of the purposes of our laboratory studies is brightness and polarimetric opposition effects ubiquitously observed in nature for particulate (regolith-like) surfaces. We studied a range of samples that are characterized with a variety of mechanical structures and albedo. A strong particle-size dependence of the negative branch of polarization for powdered dielectric surfaces was found: the larger the particle size, the narrower the opposition spike and the negative polarization branch. In Fig. 28 we show an example of measurements of a sample of red clay carried out with the instrument that covers the angle range 2 – 150°. The plot allows one to compare photometric and polarimetric phase dependencies for particles in air (single scattering) [Volten et al. JGR 2001. 106. 17,375] and when particles form a particulate surface (multiple scattering) at the two wavelengths. Figure 28 prsents data for compressed and uncompressed particulate surfaces. Analysing of these data clearly show that the main cause of the negative polarization of particulate surfaces is single particle scattering.

Figure 29 illustrates results of our measurements obtained with the laser photometer covering the angle range 0.008 – 1.5°. One can see 3 normalized photometric phase curves measured at $\lambda = 0.63$ μm: fine powders of MgO (very bright surface), carbon soot (very dark surface), and glass spherical beads with the diameter of particles near 50 μm (bright surface). Bright samples demonstrate narrow spikes of backscattering related to the coherent backscatter enhancement effect. The spherical beads also show several resonances. The measurements are used for interpretation of photometric properties of Kuiper Belt objects.