INFLUENCE OF SURFACE ROUGHNESS ON SCATTERING PROPERTIES OF WAVELENGTH-SIZE PARTICLES SIMULATING REGOLITH GRAINS.

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Introduction: Most if not all atmosphereless celestial bodies are covered by a regolith layer consisting of dust particles with complex irregular structure. The particle size varies widely. Apparently, small submicron-sized dust particles do not exist independently of larger particles but adhere to them. Variation of the number of small and large dust particles in the regolith results in differing surface structures on the large particles. Small grains on the large particles can be interpreted as surface roughness. Here we investigate the photopolarimetric properties of irregular particles comparable to wavelength with different kinds of roughness. Note that earlier investigations on the influence of surface roughness on the light-scattering properties of spherical particles comparable to wavelength have been carried out [e.g. 1].

Initial irregular particles and generation of surface roughness: As the basic irregular particle we have chosen the so-called Gaussian random particle. The algorithm for the generation of sample particles was described in [2]. As statistical parameters, we used the relative radius standard deviation $\sigma = 0.245$ and the power law index $\nu = 4$ in the covariance function of the logarithmic radius. For such parameters, the sample particles have a smoothly undulating surface (Fig. 1, on the left).

In order to compute the light-scattering properties, we use our own implementation [3] of the Discrete-Dipole Approximation (DDA) technique [4]. The main advantage of DDA over other approaches is the absence of any restriction on the shape and internal structure of scatterers. According to the general idea of DDA, we replace each initial irregular particle with an array of dipoles which are located in cubic lattice points.

In order to generate additional roughness on the Gaussian particle surface we divided all dipoles into two classes: those belonging to the surface layer and those inside the particle. A given dipole belongs to the surface layer if the number of neighboring dipoles is less than 26. Among the surface-dipole sites, a certain number of sites were randomly chosen. Half of them were marked as seed sites for material, whereas the rest were seed sites for free space. Each of the remaining surface-dipole sites obtained the same class as the nearest seed site. The varying ratio of seed-site number to the total number of sites provides us with different kinds of roughness.

In the current investigation, 100 Gaussian sample particles have been studied. The mean numbers of dipoles inside the particle and within the surface layer are 19133 and 5483, respectively. Two sets of seed sites were used: 3000, i.e., 1500 for material and 1500 for free space (Fig. 1, center) and 300 (Fig.1, on the right). The first and second sets of seed sites result in small-scale and large-scale roughness on the particle surfaces, respectively. All examples look realistic in comparison to real planetary regolith particles.

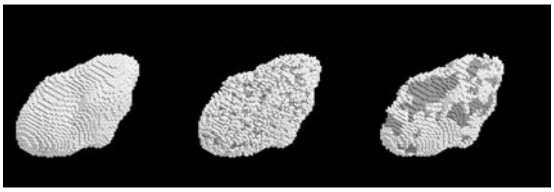
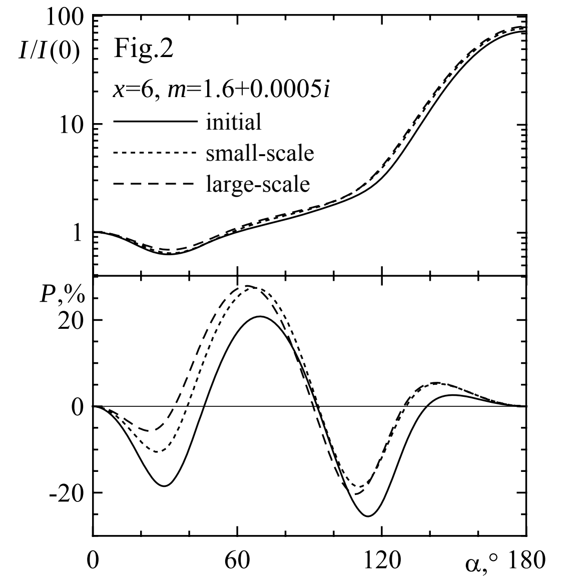


Fig. 1

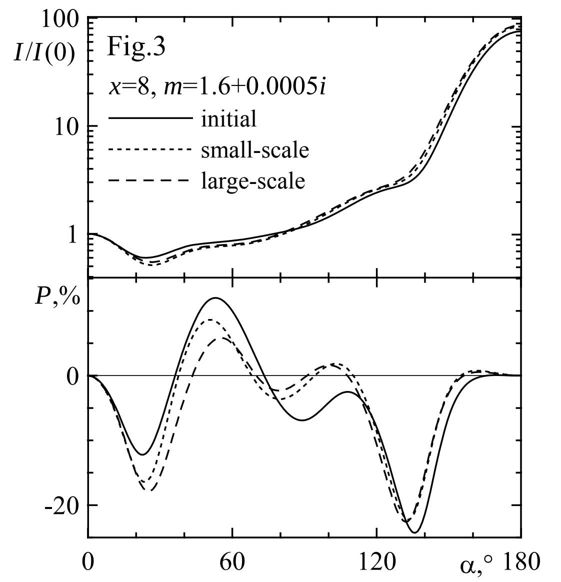
Results of computations and discussion: Here we present results of phase curves of intensity and degree of linear polarization for Gaussian particles with and without surface roughness. Computations were carried out for the refractive index $m = 1.6 + 0.0005i$ which is close to the refractive index of pyroxene glasses in visible light [5]. The size parameter $x = 2\pi r_{cs}/\lambda$ was varied from 2 to 12 with the step of 2 (r_{cs} is the radius of the circumscribing sphere of the largest sample particle and λ is the wavelength). On the average the Gaussian sample particles occupy only about 0.14 of the volume of the circumscribing sphere, thus the relationship between the size parameter of the circumscribing sphere and size parameter of the equal-volume sphere is given as $x_{eq} = 0.52 \cdot x$. Note that at $\lambda = 0.5$ μm the actual size of the particles considered varies from 0.32 to 1.9 μm. Here we show the curves calculated for size parameters $x = 6, 8, 10$.

The light-scattering properties of each sample particle were averaged over orientations using no less than 12 different orientations. In some cases, this number reached the value of 60. The choice for the number of orientations was based on the necessity to obtain a statistically reliable result. For a given set of parameters, the same number of orientations was applied to all particle samples. Thus, the total number of sample particles with differing orientations was between 1200 and 6000.

In Figure 2, phase curves of normalized intensity (upper panel) and degree of linear polarization (lower panel) for unpolarized incident light are

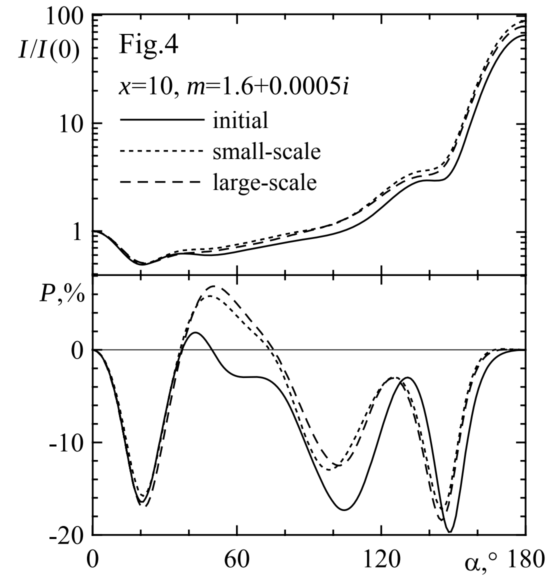


shown for $x = 6$. One can see rather similar intensity behaviors independently of the type of particle surface, though both kinds of roughened particles produce intensity curves more similar to one another than to those for the initial irregular particles. Contrary to the intensity, the linear polarization is more sensitive to features on the particle surfaces: the curves differ noticeably. We note that, for small phase angles, all polarization curves have significant negative polarization branches (NPB). The NPBs as well as full polarization phase curves depend on the type of particle surface–in the present case, NPBs



are neutralized with increasing surface roughness.

Figure 3 presents the same as Figure 2 for $x = 8$. As earlier, the intensity phase curves are similar; whereas, the polarization curves strongly depend on surface roughness. In this case, however, the NPB becomes more pronounced with increasing surface roughness. Note also that, generally, both kinds of



roughened particles produce polarization phase curves that are closer to one another than to that for the initial irregular particles.

In Figure 4 results are shown for $x = 10$. Again, only a small difference in the intensity curves is seen. Nevertheless, the curves of the roughened particles are still more similar to one another. The same similarity is observed for the polarization phase curves. Contrary to the previous cases, the NPB is practically independent of surface roughness.

Conclusion: Our simulations show:

1. Polarization phase curves are more sensitive to surface roughness than intensity phase curves for irregular particles having sizes comparable to the wavelength;
2. Photopolarimetric properties resulting from the two types of surface roughness are closer to one another than to those of the initial irregular particles; and
3. The behaviour of the NPB is complex. Increasing the surface roughness can make the NPB more or less pronounced.

All the obtained results are potentially useful for the development of a remote sensing technique to estimate variations of morphology of planetary regolith particles.

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