

NEGATIVE POLARIZATION OF AGGLOMERATE PARTICLES WITH VARIOUS DENSITIES

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ABSTRACT. We study the negative polarization produced by agglomerate particles of various density. We found that all types of agglomerates studied reveal similar dependence of negative polarization minimum P_{\min} and its location α_{\min} on particle size and refractive index.

1. Introduction

The phenomenon of negative linear polarization accompanies backscattering of sunlight by cometary dust particles (e.g.[1]). Note, in the case of randomly oriented target particles, the definition for the degree of linear polarization P can be reduced as follows: $P = (I_{\perp} - I_{\parallel}) / (I_{\perp} + I_{\parallel})$, where I_{\parallel} and I_{\perp} denote the intensity of the scattered light being polarized in and perpendicular to the scattering plane, respectively. Therefore, the negative polarization simply means that $I_{\parallel} > I_{\perp}$.

In general, the negative polarization depends on the wavelength of light λ and phase angle α . Note that phase angle α is a supplementary angle to the scattering angle θ , so $\alpha = 180^{\circ} - \theta$. In practice, the angular dependence of the negative polarization appears as a branch of the negative polarization (NPB) at $\alpha \leq 30^{\circ}$. Two important quantities that characterize the NPB are the minimum of linear polarization P_{\min} and the phase angle of the minimum location α_{\min} . In this paper, we study the dependence of both these parameters on the structure of agglomerate particles.

2. Computation of light scattering and models of agglomerate particles

Using the discrete dipole approximation (DDA) [2], we compute light scattering by agglomerate particles with three different types of structure. All types of particles are generated with the same algorithm that is comprehensively described, e.g., in [3]. Note that, to some extent, light-scattering properties of two kinds of particles, namely, so-called *agglomerated debris particles* and *pocked spheres* have been studied in [3]; there, one can find also more details on the generation procedure.

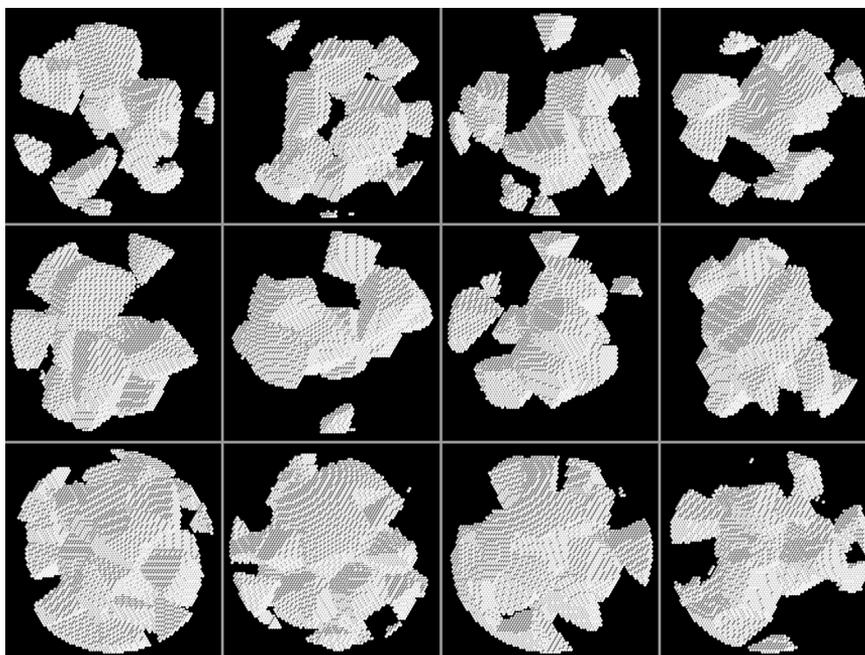


Figure 1. Four sample particles of sparse agglomerates (top), agglomerated debris particles (middle), and pocked spheres (bottom).

A new type of particle could be conditionally called a *sparse agglomerate*. The parameters for generation of sparse agglomerates are the same as for agglomerated debris particles, except for the number of seed cells of empty space randomly allocated throughout the internal volume. In the case of agglomerated debris particles, this number is set to 20; whereas, in the case of sparse agglomerates it is 50.

Four examples for each type of agglomerate particles are shown in Fig. 1. One can see that all the particles reveal essentially non-spherical, highly irregular structure. However, the radius of the circumscribing sphere nearly coincides for all the agglomerates. Packing density ρ , i.e., the ratio of material volume over the entire circumscribing sphere is 0.169 for sparse agglomerates, 0.236 for agglomerated debris particles, and 0.336 for pocked spheres. Thus, through these three types of agglomerate particles, ρ varies by a factor of two.

We repeat computations of light scattering for three different refractive indices $m = 1.313 + 0i$, $1.5 + 0.1i$, and $1.6 + 0.0005i$, which approximately represent water ice, organic material, and Mg-rich silicates, i.e., the most abundant species of comets [4]. Size parameter $x = 2\pi r/\lambda$ (where, r is the radius of the circumscribing sphere) is varied from 1 to 36 for icy particles, 32 for organic particles, and 26 for silicate particles (except the pocked spheres, when the upper value of x is limited to 24 due to convergence limitations). It needs to be emphasized that, in all the cases, we perform averaging of light-scattering properties over a minimum of 500 particle shapes.

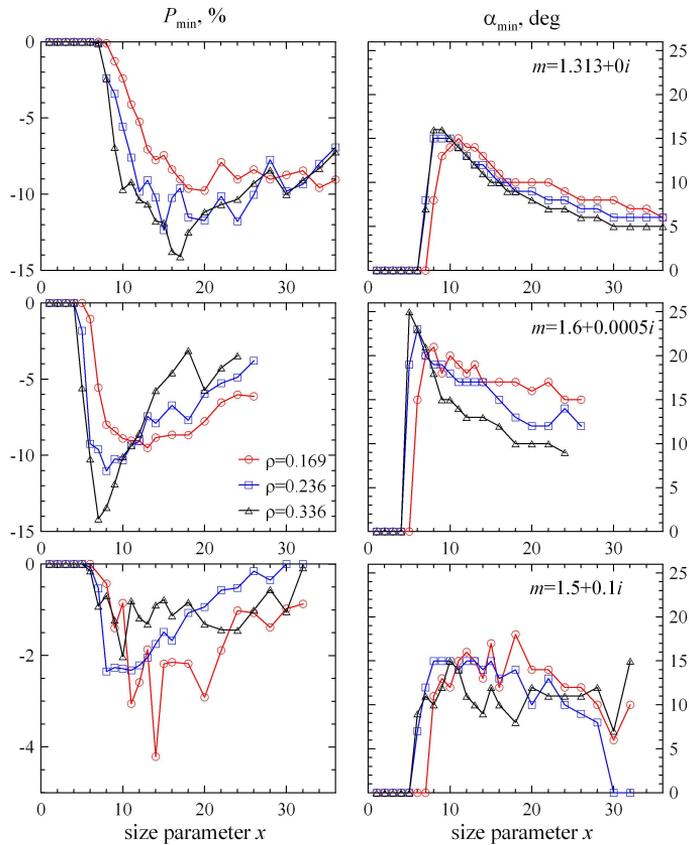


Figure 2. P_{\min} and α_{\min} vs. size parameter x for agglomerate particles with various packing density ρ .

3. Results and discussion

Figure 2 presents results of computations of P_{\min} (left) and α_{\min} (right) as a function of the size parameter x . The top row shows data for $m = 1.313 + 0i$, the middle for $m = 1.6 + 0.0005i$, and the bottom for $m = 1.5 + 0.1i$. As one can see, different types of agglomerates reveal quite similar profiles for both parameters. For instance, in all cases, the NPB is not observed at $x < 4 - 8$ (i.e., $P_{\min} = 0$ and $\alpha_{\min} = 0$). The NPB appears in a narrow range of size parameters $x_{\text{app}} = 5 - 8$ and grows fast with size, reaching maximal negative polarization at $x_{\text{max}} = 7 - 17$. Note, such dependence of the NPB on x can be responsible for the blue color of the negative polarization that was observed in comet 17P/Holmes [5]. We stress that the approximate relation $x_{\text{max}} \approx 2x_{\text{app}}$ holds for all non-icy particles.

Though P_{\min} varies significantly with packing density ρ , it is important to note that even sparse agglomerates with $\rho = 0.169$ have a substantial NPB. However, in the case of highly absorbing material, the amplitude of the NPB produced by sparse agglomerates may

even exceed those of more dense agglomerated debris particles and pocked spheres. These results are consistent with our previous study of light scattering by exploding particles [6]. Finally, we note that the location of the polarization minimum α_{\min} reveals a clear tendency to decrease while x increases.

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