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Polarization of non-spherical dust particles modelled with different computational techniques

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Abstract

Interpretation of polarimetric observations of cometary, interplanetary, and circumstellar (disk) dust requires computer modeling that simulates light scattering by the dust particles. Since the dust particles have complex shape and structure, those simulations require computer codes capable to accurately represent light scattering by irregular inhomogeneous particles. Recently several powerful codes have been developed to model such particles. In this paper we compare the phase curves of polarization in dependence on particle size and composition, computed using some popular computer models. We provide recommendations to the modelers regarding the applicability of the codes to particles of different composition and size.

1. Light scattering by non-spherical particles

In this study we consider three types of non-spherical particles that are often used to simulate light scattering by cometary and interplanetary dust: rough particles, irregular particles, and aggregates. We model their light scattering characteristics using the codes described below.

1.1 Rough particles

We simulate rough particles using the model of rough spheroids that has been recently used to simulate photopolarimetric properties of terrestrial aerosols [1] and cometary dust [2]. In this study, as in [2], for each size, we considered a mixture of randomly oriented spheroids of the same effective volume but their aspect ratio varied from 1 to 3.0 for prolate and 0.3 for oblate spheroids. The roughness of the spheroids was described by parameter σ that is the dispersion of the tilt distribution of the facets that randomly cover the surface of the spheroid. We use a software package presented in [1].This package allows computations of light scattering by a mixture of spheroids of axis ratios from 0.3 to 3.0 and covers the size parameter (x) from 0.012 to 625. For small spheroids, the simulations were performed using the T-matrix method, for spheroids with sizes x>18, an improved geometric optics method was used [see 1, 2 for details].

1.2 Irregular particles

In this study we present irregular particles as Gaussian particles, which are the particles created by disturbing a sphere of a given radius the way that the sphere radii become randomly lognormally distributed [3]. Two radial distances relate to one another through “correlation angle,” changing which from 0 to 90^{o} we can model a variety of particles from spheres to particles of a random complex shape. In this study we considered particles of correlation angle 20^{o}. Their light scattering was calculated using Sh-matrix approach [4]. Being based on the T-matrix technique, this approach separates the shape-dependent factors from the size- and refractive-index-dependent factors, presenting the shape as a shape matrix.

1.3 Aggregates

Aggregated model of particles is believed to be the most realistic model of cometary and interplanetary dust particles. We simulate light scattering by aggregates using the T-matrix approach to the solution of the Maxwell equations for clusters of spheres [5]. To make the model most realistic for the case of cometary dust, we considered the radius of the monomers equal 0.1 μm and the Halley-dust composition.

2. Computations

We accomplished computations for rough and irregular particle for the range of particle sizes 0.05 – 5 μm and for a variety of compositions expected for cometary and disk dust: ice, silicates, tholin, cosmic organics [6], and Halley dust (mixture of silicates, carbon, organics and iron), solid and porous. Then we calculated the differences between the polarization for a particle of the same size and composition obtained with rough spheroid and Gaussian particle model. The results for wavelength 0.45 μm and for the solid and 85% porous Halley dust are shown in Fig. 1.

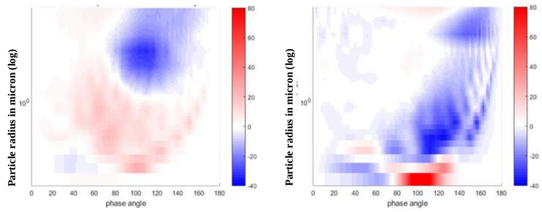

Figure 1: Difference between rough and irregular particle polarization as a function of phase angle (x axis) and particle radius (y axis) for 85% porous (left panel) and solid (right panel) Halley dust. The step in the particle radius was 0.05 micron.

We also compared the results of the rough-spheroid and Sh-matrix computations with the T-matrix results for Halley-dust aggregates of the same radius of gyration (Figure 2).

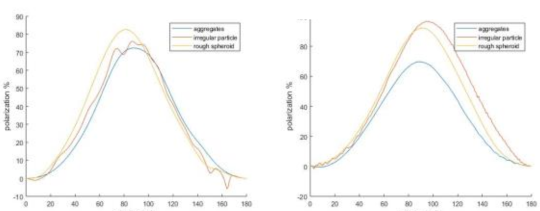

Figure 2: Polarization vs. phase angle for aggregate, rough, and irregular Halley-dust particles of radius 0.25 (left panel) and 1.65 (right panel).

3. Discussion

Figures 2 and 3 demonstrate that the considered types of particles have similar polarization phase curves; however, they differ in maximum/minimum value of polarization and location of the maximum/minimum. The difference strongly depends on the particle size and composition. The difference between rough and irregular particles is smaller for transparent materials, and increases with increasing absorption; for smaller particles, polarization is larger for rough particles and for larger particles, it is larger for irregular particles. The difference between rough/irregular particles and aggregates is smaller for smaller particles and increases as the particle size increases.

4. Conclusions

Our study shows that all considered models of particles rather well represent polarization of cosmic dust in the case of not very absorbing particles of size $x<10$. For larger or/and absorbing particles, neither rough nor irregular particles are capable to reproduce the light scattering characteristics of realistic aggregated particles as they cannot account on electromagnetic interaction between the particle constituents.

Acknowledgements

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