Modeling photopolarimetric characteristics of cosmic dust using rough porous spheroid model

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Abstract

The studies of a cosmic dust in a variety of environments (interstellar, circumstellar interplanetary and cometary dust) indicate that their light scattering properties are dominated by porous, fluffy particles, composed of many small grains coalesced together due to grain-grain collisions, dust-grain interactions and various other processes. Using aggregate dust model, several investigators have successfully modeled extinction properties of interstellar dust and photopolarimetric properties of cometary dust. The main disadvantage of aggregate dust model is that one cannot consider particle size larger than couple of microns due to limitations of computer memory and speed of currently available computers, whereas IR observations and in situ data indicate a significant number of rather large particles in the cometary dust. In this study, we use the software package developed by Dubovik et al. (2006, J. Geophys. Res., 111, D11208) to check whether rough porous spheroid particle could reproduce the optical characteristics of aggregates. We start with a systematic study of light scattering characteristics of a single aggregate and equal-volume spheroid of corresponding porosity. We explored different light scattering properties, viz. scattering efficiency, albedo, color and polarization, of single aggregates using rough spheroid model. Then we consider a mixture of randomly oriented spheroids with 25 bins of the axis ratio from 0.3 (oblate spheroids) to 3.0 (prolate spheroids) and 41 size bins covering the size parameter from 0.012 to 625 ($0.001\mu m \leq r \leq 65\mu m$ for $\lambda = 0.65\mu m$). The pre-calculated kernels in the software package allow fast, accurate, and flexible modeling of different size and shape distributions. The roughness of spheroids is defined by a normal distribution of the surface slopes and its degree depends on the standard deviation of the distribution, which is zero for smooth surface and greater than zero for rough surface. We present our results of a systematic investigation of the angular and spectral dependencies of intensity and polarization obtained with the rough spheroids model and discuss possible application of this model to cometary dust. We have found that the rough spheroid model could reproduce observational results using a mixture of porous spheroids made of absorbing material (compositionally similar to the comet Halley dust) and compact silicate spheroids that is consistent with the findings of the missions to comet Halley and analysis of the Stardust returned samples.

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