COMPUTATIONAL MODEL OF LIGHT SCATTERING BY IRREGULAR PARTICLES: APPROXIMATION TO POLARIZATION MEASUREMENTS OF COMETARY DUST

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Abstract: We present a computational model to obtain the scattering properties of a distribution of non-spherical particles at visible wavelengths and its application to cometary dust and to laboratory scattering measurements of cometary dust analogue. We have calculated the size-shape-averaged scattering matrix elements for both regular and irregular compact shapes and the size-averaged scattering matrix elements for the same irregular porous shape. We have also done calculations for two compositions. The mixture of silicate plus carbon is more appropriate to reproduce the cometary measurements. We have also found that it is possible to approximate the linear polarization curve of cometary dust by using a rectangular prisms distribution in which the most elongated shape prevails and by averaging in sizes for a irregular porous shape. We have also obtained that the irregular compact particles approximates better the laboratory measurements of cometary analogue.

1 Introduction

There is a certain consensus in the astrophysics community to establish that the cometary grain has a porous structure, forming aggregates of a certain number of monomers. This reasoning is based on the formation models of cometary nucleus [1] and on certain observational measurements. Nevertheless, laboratory experiments have shown that compact mineral particles with analogous composition to cometary dust exhibit similar properties [2]. Therefore, the irregularity and compactness of the particles have been the two fundamental physical parameters considered in our study. In an attempt to shed some light on the possible characteristics of cometary particles, dealing with the composition, the shape and the porosity degree, we have carried out a systematic study of the overall scattering matrix elements by considering a distribution of sizes and shapes for both regular and irregular particles and considered a certain degree of porosity in same cases. To compute the size-averaged scattering matrix elements we have considered sizes ranging from 0.1 μm to 100 μm and assuming a power law of index -1.8 as a size distribution. This size distribution has been chosen according to the in situ measurements of the spacecraft Giotto in comet Halley. The results have been compared with measurements of the phase function, and mainly, with the variation of the degree of linear polarization versus phase angle of cometary dust [3, 4] and with laboratory measurements of cometary analogue [2].

2 The model

The model is based on the idea that is possible to obtain the overall single scattering properties of an ensemble of particles by averaging the single scattering properties of each particle, according to the scattering cross section. For calculations of the single scattering properties of each particle two different techniques have been used, namely the Discrete Dipole Approximation (hereafter DDA) [5, 6] for the particles with sizes similar to the wavelength of the incident radiation and the Ray Tracing [7] for larger particles. An extensive explanation about the model and the calculations can be found in previous papers [8, 9, 10]. Two compositions have been considered in the calculations. The first one is dirty ice plus silicate with carbon inclusions (hereafter Mixture 1) and second one is silicate plus carbon (hereafter Mixture 2). For calculations with compact particle we have considered two different shapes distributions which consist of a rectangular prisms distribution with different aspect ratios such as 1:1:1, 5:5:1, 5:1:1, 5:2:1, 5:4:2, 4:3:4, 4:2:4, 5:3:1 and 5:4:1 and an irregular distribution whose shape has been generated making use of the options DW1996 and BLOCKS of the *calltarget* function of Draines DDA code. For calculations with porous particles we have selected the shape DW1996 and generated by removing randomly 50% of dipoles a certain degree of porosity.

3 Results and conclusions

The calculations have shown that it is possible to approximate the scattering matrix elements by using both compact and porous particles, being the -F_{12}/F_{11} ratio the linear polarization for unpolarized incident light. In the case of compact particles one of the best adjustment to linear polarization curve of comets is obtained for a rectangular prisms distribution in which the elongated shape (5:1:1) prevails for the Mixture 2 as is shown in the Figure 1. The adjustments using the compact irregular shapes for the Mixture 2 are not at all satisfactory to reproduce the cometary measurements, however they are useful for reproducing the laboratory measurements of cometary analogue [9]. We have also found that the size-averaged scattering matrix elements obtained for each of the compact irregular shapes do not show differences as large as the results obtained for each of the compact rectangular prisms, in which the differences are more pronounced, especially for the most extreme shapes. However, if we also average in shapes by considering uniform shape distributions then the differences between the phase function and the linear polarization become almost inappreciable for the two cases. Finally, calculations with porous irregular particles turn out to be more adequate to approximate the negative branch of the linear polarization of comets, however it is necessary to consider sizes larger than the wavelength of the incident radiation in other to reach values of the maximum of polarization near the cometary measurements as is shown in Figure 2. Subsequent studies [10] shed some light on this concern.

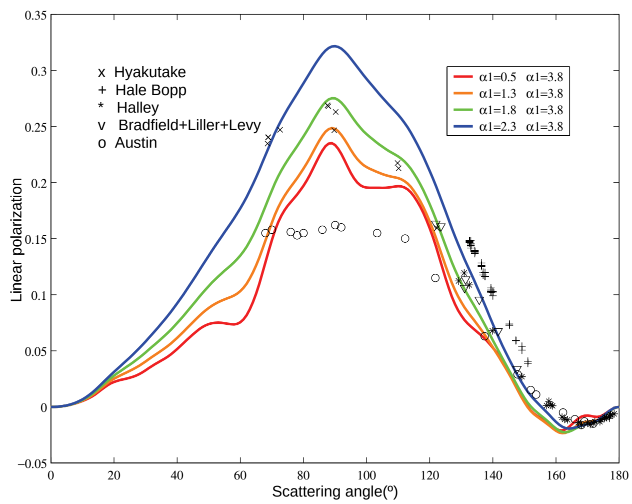

Figure 1: The size-shape-averaged linear polarization curves for a rectangular prisms distribution prevailing the elongated shape and for a power law of negative indices of α_2=3.8 for larger size and α_1 varying from 0.5 to 2.5 for sizes between 0.1 and 1.0 μm as size distribution for the Mixture 2 and linear polarization measurements of comets such as Hyakutake, Hale-Bopp, Halley, Bradfield+Liller+Levy and Austin.

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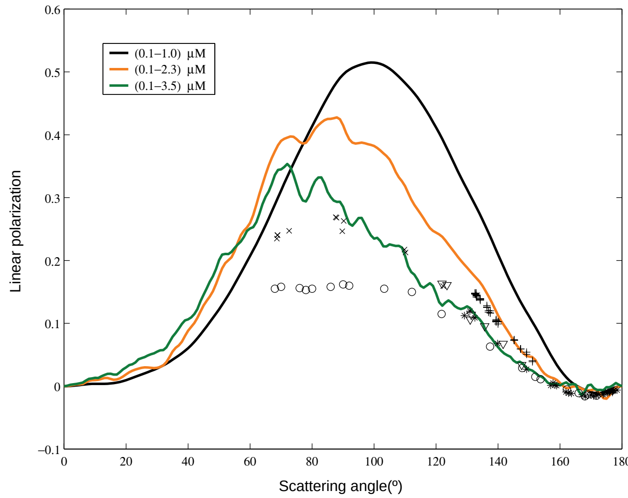

Figure 2: The size-averaged lineal polarization curve for an irregular particle (DW1996) with sizes varying: a)(0.1-1.0)μm, b)(0.1-2.3)μm and c)(0.1-3.5)μm for power law of negative index equal -1.8 for the Mixture 2 and linear polarization measurements of comets such as Hyakutake, Hale-Bopp, Halley, Bradfield+Liller+Levy and Austin.

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