1.3.6 SCATTERING FUNCTIONS OF DIELECTRIC AND ABSORBING IRREGULAR PARTICLES

R. Zerull

Bereich Extraterrestrische Physik, Ruhr-Universität Bochum, FRG

Introduction

Most model computations for the analysis of interplanetary dust are based on scattering functions of homogeneous spheres (Mie-theory). To investigate the influence of this restriction, scattering properties of nonspherical particles were studied by microwave analog experiments. The results of earlier investigations on dielectric rough spheres, cubes and octahedrons (Zerull, 1973; Zerull and Giese, 1974) may be shortly summarized as follows: Roughness ($\sim \frac{1}{10}$ wavelength) does not significantly change the scattering behaviour of spheres, whereas cubes and octahedrons scatter evidently different than equivalent spheres. The dominant differences are increased intensity at medium scattering angles but no further increase towards backscattering, and nearly neutral polarization. These results encouraged to continue the investigations with really irregular particles of dielectric as well as absorbing material.

Definitions

The scattering properties of irregular particles are illustrated by plotting the averaged scattering functions I_1 and I_2 or the first Stokes parameter $I = I_1 + I_2$ and the degree of linear polarization $P = (I_1 - I_2) / (I_1 + I_2)$, respectively. The size parameter $\alpha = \pi D/\lambda$ (D = diameter, λ = wavelength) is referred to spheres of equal volume, with which the results are compared. The size distribution of the particles is assumed in this paper to be a power law $dn \sim \alpha^{-2.5} d\alpha$, but other size distributions can easily be simulated using the same measuring data. The physical properties of the particles are given by the complex refractive index $m = m' - m''i$.

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Dielectric Irregular Particles

The particles treated in this section are nearly purely dielectric (m=1.5 - 0.005i). There are two different types of irregular particles. Typical examples are shown in fig.1. Following van de Hulst I call them "convex" and "concave" bodies. For "convex" particles theoretical predictions concerning the averaged geometrical cross section and the reflected part of the scattered radiation can be made, not so for "concave" particles (van de Hulst, 1957). In fig. 2 the averaged scattering functions of polydisperse mixtures are plotted for the size interval 1.9 ≤ α ≤ 5.9. This size interval includes the first maximum of the extinction cross section of the equivalent spheres. This maximum does not occur in the case of irregular particles (Hodkinson, 1963). Therefore and because of the close relationship between extinction cross section and forward scattering, intensity within the diffraction lobe is lower for the irregular particles than for the equivalent spheres. For scattering

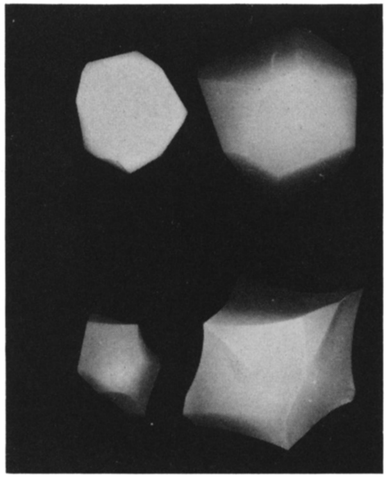

Fig. 1: "Convex" and "concave" particles.

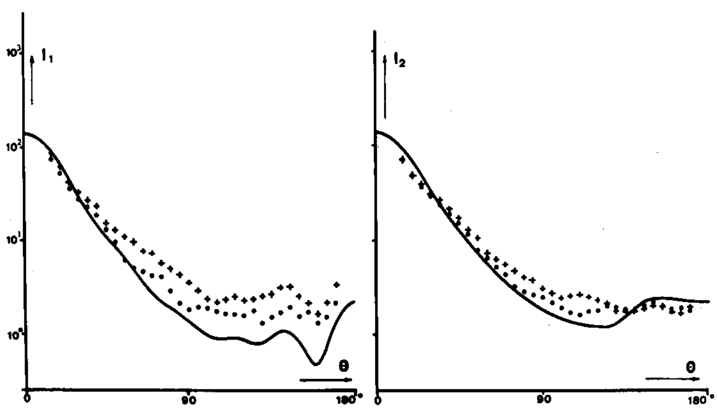

Fig. 2: Scattering functions $1.9 \leq \alpha \leq 5.9$ $m = 1.5 - 0.005i$

—— spheres
•••• convex particles
++++ concave particles

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angles $\theta \gtrsim 30^\circ$ irregular particles show increased intensity, especially evident for the "concave" bodies. For both types of irregular particles the increase of I_1 is stronger than of I_2, so polarization is shifted to more positive values.

Fig. 3 shows the averaged scattering functions of polydisperse mixtures of the irregular particles and equivalent spheres for the size interval $5.9 \leq \alpha \leq 17.8$. There is a good correspondence in the diffraction lobe, as far as it could be measured. For scattering angles $30^\circ \lesssim \theta \lesssim 150^\circ$ both types of irregular particles show increased intensity, up to the factor 5. Enhanced backscattering is produced by the "convex" particles, not quite as marked as by the spheres, whereas the scattering of the "concave" particles is nearly isotropic for $\theta \gtrsim 100^\circ$. Enhancement of intensity is much more significant for I_1 than I_2. So, by irregular particles of this size, too, polarization is shifted to more positive values.
In fig. 4 the polarization properties of the "convex" and "concave" bodies are plotted separately considering sizes $1.9 \leq \alpha \leq 17.8$. No type of the irregular particles shows the strong negative polarization which is typical for the equivalent spheres. Against that, their polarization behaviour is much more neutral, small negative values dominating for the "convex" bodies, small positive values dominating for the "concave" ones.

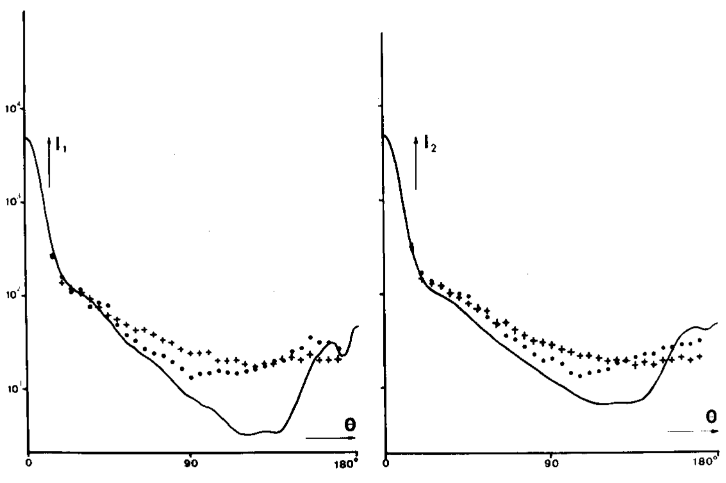

Fig. 3: Scattering functions $5.9 \leq \alpha \leq 17.8$ $m = 1.5 - 0.005i$

—— spheres
•••• convex particles
++++ concave particles

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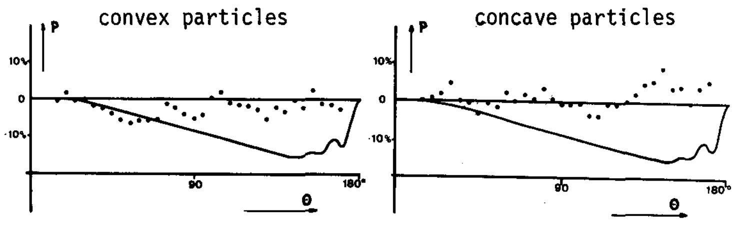

Fig. 4: Polarization
$1.9 \leq \alpha \leq 17.8$
$m = 1.5 - 0.005i$

—— spheres
•••• irregular particles

Absorbing Irregular Particles

There are three conditions for theoretical treatment of the scattering properties of randomly oriented irregular absorbing particles: Their shape must be convex, they must be big enough for application of geometrical optics, and absorption has to be strong enough to ensure, that the refracted part of the radiation is totally absorbed. In that case the scattering diagram is completely determined by diffraction and Fresnel reflection only.

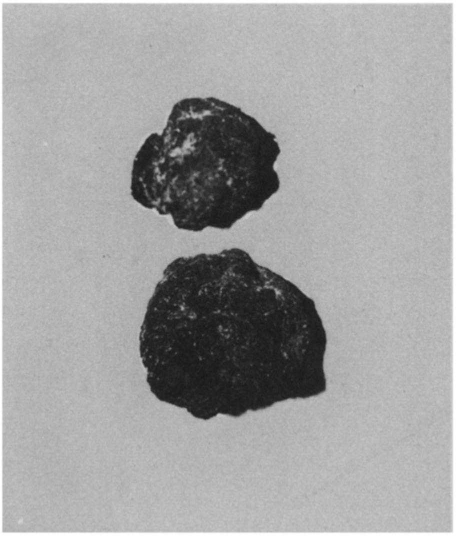

Fig. 5: Irregular absorbing particles.

The scattering bodies discussed in this section do not satisfy the three conditions mentioned above. Typical examples are shown in fig. 5. Their shape is neither purely convex nor concave. The refractive index is 1.45 - 0.05i, the size parameter is $9.8 \leq \alpha \leq 17.3$. In fig. 6 the scattering properties of the irregular absorbing particles are compared to equivalent absorbing spheres.

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The scattered intensity of the irregular particles is higher up to factor of 3. Most interesting is the run of the polarization.

Here the irregular particles approximate the theoretical Fresnel reflection curve much better than spheres of the same size.

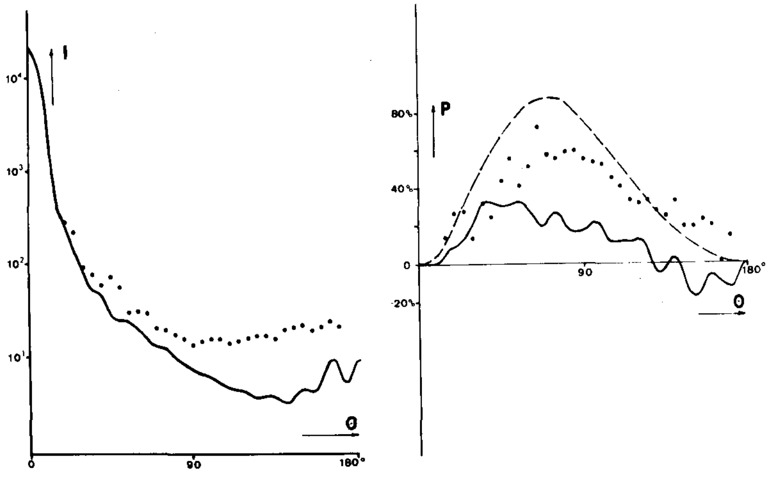

Fig. 6: Total intensity and polarization $9.8 \le \alpha \le 17.3$, $m = 1.45 - 0.05i$

—— spheres
•••• irregular particles
---- Fresnel reflection

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