LABORATORY RESULTS ON POLARIZATION PROPERTIES OF ELONGATED PARTICLES AND COMPARISONS TO DUST IN THE TAIL OF COMET IKEYA-SEKI (1965 VIII)

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ABSTRACT. Data obtained through microwave analog measurements are used to compare optical polarization characteristics of silicate particles ranging in shape from spheroids and cylinders to chains of spheres. It is confirmed that the dependence of the degree of polarization on scattering angle is a powerful indicator of particle shape. The reversal and steep gradient in the degree of polarization found by Weinberg and Beeson (1976a,b) in the dust tail of comet Ikeya-Seki (1965 VIII) is suggestive of laboratory measurements corresponding to 1.6 μm long, 0.4 μm in diameter silicate cylinders.

1. INTRODUCTION

Krishna Swamy (1978) showed that the run of the degree of polarization with scattering angle observed in the tail of comet Ikeya-Seki (1965 VIII) could result from size segregation among spherical particles. Segregation along the tail is expected due to faster diffusion away from the tail for low mass particles. But spherical particles are probably rare in a disintegration event. Cubes or other rough shapes may be a better approximation. Sekanina and Farrell (1980) found independent evidence for elongated grains in the tail of comet West (1976 VI), and suggested that chain like aggregates may have been common. Schuerman et al. (1981) and Zerull (1985) concluded that there are marked deviations from Mie polarization patterns for the case of non-spheres. The degrees of polarization produced by chains of five spheres, similar sized circular cylinders and spheroids are compared to illustrate the effect of detailed shape including sharp edges. In this paper, we concentrate on the degree of polarization. This quantity, a ratio of intensities, is independent of the (unknown) number of particles along the line of sight. In addition, the angular dependence of the degree of polarization is found to be a powerful indicator of particle parameters (see also Schuerman et al., 1981 and Zerull, 1985).

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2. OBSERVED DEGREE OF POLARIZATION

Comet observations covering several scattering angles involves more than one set of particles. Either the dust is observed at substantially different times or is located at different distances from the comet's nucleus (unless observations are made simultaneously from more than one point in space). Weinberg and Beeson's (1976a,b) multicolor observations of brightness and polarization cover scattering angles θ from 116 to 136 degrees, with detailed results given at 5300 Å along the tail axis (Figure 1). Krishna Swamy (1978) estimated that the dust responsible for these data range from 0.8 to 1.6 AU from the cometary nucleus.

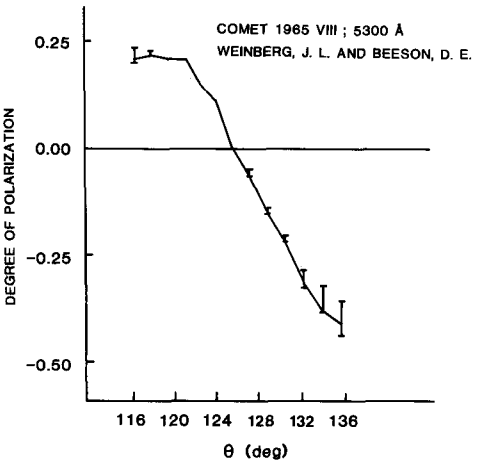

Figure 1. Angular dependence of the degree of polarization in the tail of comet Ikeya-Seki.

3. SCATTERING RESULTS

All scattering data are averaged over a uniform distribution of orientations to simulate scattering by an ensemble of randomly oriented particles. To illustrate the effects of particle shape, particles of equal surface area are compared. For the cylinders and chains of spheres, scattering data were obtained experimentally using the microwave analog

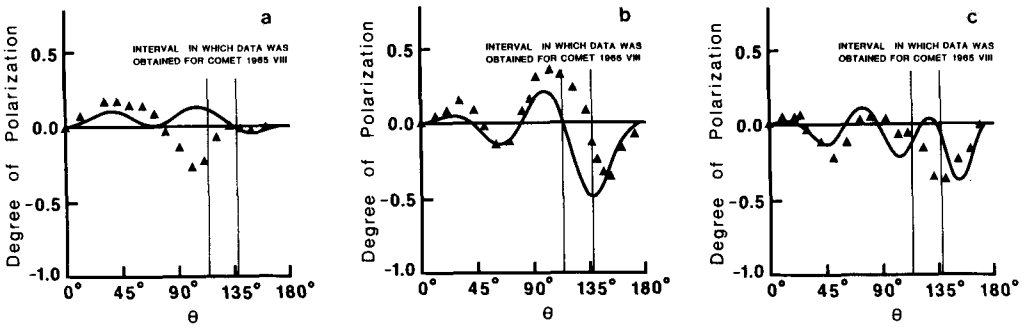

Figure 2. Scattering signatures averaged over uniform distribution of orientations of circular cylinders (triangles, measured), and prolate spheroids (solid curve, computed). In (a) both particles have surface areas corresponding to a 0.34 μm radius sphere, in (b) to 0.43 μm and in (c) to 0.51 μm.

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technique (Schuerman, 1980). The dimensions of the target and the wavelength are scaled by the same amount. The index of refraction ($m = 1.61 - i\ 0.004$) of the target material (acrylic) at the laboratory frequency 9.417 GHz, resembles that of silicates at optical frequencies. Scattering by the spheroids was computed using a code developed by Schaefer (1980).

In Figure 2, the degree of polarization of scattering from three sets of sizes 4:1 aspect ratio silicate cylinders and prolate spheroids are compared. The strong dependence of the angular distribution of the degree of polarization on shape and size makes the correlation between observations (Figure 1) and scattering by 0.4 μm diameter cylinders remarkable (Figure 2b). A size increase towards high scattering angles, similar to the one postulated by Swamy would further improve this fit. With similar surface area spheroids the neutral point occurs at much lower scattering angles. The 20% (linear dimensions) smaller particles (Figure 2a) produce negligible negative polarization. With 20% larger particles (Figure 2c) there is little positive polarization in the backscattering hemisphere.

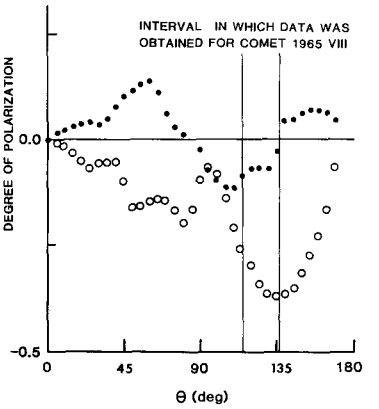

Figure 3. Polarization data averaged over uniform distribution of orientation for chains of five contacting spheres. The radii of the surface equivalent spheres are 0.41 μm (dots) and 0.58 μm (circles).

Similar sized chains of spheres (Figure 3) produce a much weaker angular dependence of the degree of polarization in the observed interval where it remains negative.

4. CONCLUSIONS

Circular cylindrical particles of materials, sizes and elongations corresponding to four times the estimated core size of interstellar dust particles (Greenberg, 1978) could have been an optically important dust-component in the tail of comet Ikeya-Seki (1965 VIII) at the time it was observed by Weinberg and Beeson (post-perihelion). Although the overall shapes of the model particles were similar, the scattering signatures efficiently discriminated amongst their detailed shapes. The observations fit the scattering by dust with sharp edges (which are expected from a breakup event). Comparisons to the scattering by these and several other particles indicate that the polarization in the tail of comet Ikeya-Seki may be relatively efficient at discriminating amongst particle shapes and material. Nevertheless, silicate cylinders are not

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claimed to be a unique alternative to Krishna Swamy's interpretation. The combination of an unusually strong dependence of the observed degree of polarization on scattering angle and the sensitivity of this parameter to particle shape and size (over a wide range), appear to imply a narrow size and shape distribution of the dust or a well defined variation along the tail. The observations do not fit the polarization produced by similarly sized chain-like aggregates.

5. ACKNOWLEDGEMENT

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