1.3.7 THE COMPATIBILITY OF RECENT MICROMETEOROID FLUX CURVES WITH OBSERVATIONS AND MODELS OF THE ZODIACAL LIGHT

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Increased sophistication in both, direct impact detectors and zodiacal light measurements encourages to discuss the compatibility of the results obtained by these quite different methods of investigating interplanetary dust. Taking recent measurements of particle fluxes and velocities obtained by the space missions of Pioneer 8/9 (Berg and Grün 1973), Heos 2 (Hoffmann et al. 1975), and comparing them with submicron-sized craters on lunar surface samples (Schneider et al. 1973, Fechtig et al. 1974) there seem to be two types of interplanetary dust populations: larger ($>10^{-12}$g) micrometeorites orbiting around the sun as the classical zodiacal dust cloud and a second component of very small ($<10^{-12}$g) particles coming radially from the direction of the sun with high velocities (>50 km/s). On the basis of the flux data referred to above and adopting for both components velocities of 10 or 50 km/s relative to the detector, respectively, a differential distribution function $n(a) \cdot da$ was found for the particle radii (a) as shown at a logarithmic scale in fig. 1. A density of 3 g/cm^3 was adopted in order to convert particle masses into radii. The regions A, B, C (see Table 1) correspond approximately to the regimes of "submicron particles", the classical zodiacal cloud particles, and the meteoritic component of the interplanetary dust complex. From this information the brightness $I(\varepsilon)$ of the zodiacal light in the ecliptic plane can be computed as a function of elongation by approximating the distribution function n(a) in the different regions by simple power laws $a^{-\kappa} \cdot da$ and by adopting a resonable scattering function $\sigma(\theta)$ for the average scattering behaviour of one particle of the mixture depending on the scattering angle θ. By use of an inverse ($\nu = 1$) decrease of particle number densities $n = n_o \cdot r^{-\nu}$ with solar distance r(AU), where n_o is the number density at r=1 AU,

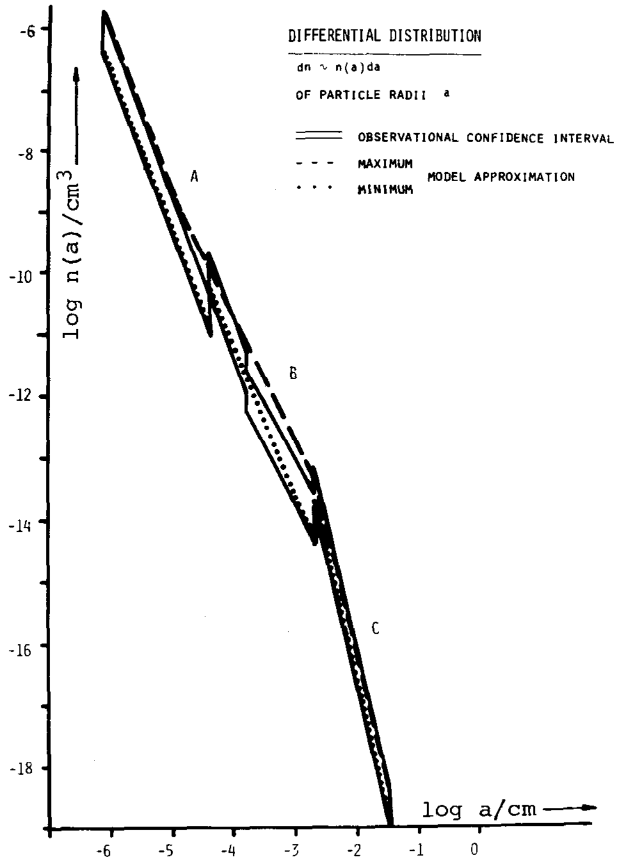

Fig. 1: Models Approximating Micrometeorite Fluxes

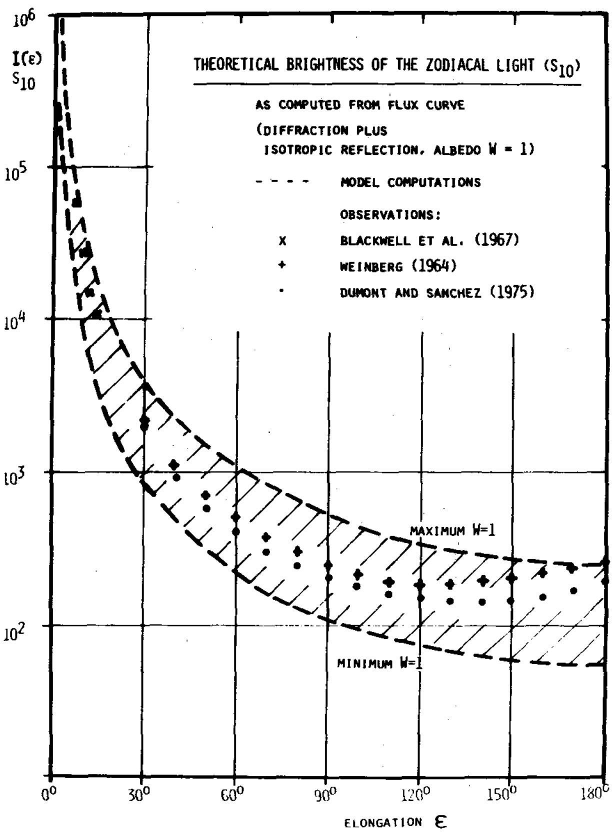

Fig. 2: Zodiacal Light

one obtains with a particle size distribution law $n(a)da \sim a^{-\kappa}da$ in the different intervals of sizes (Table 1) the intensity of the zodiacal light (in stars of 10th magnitude per square degree, S_{10}) as shown in fig. 2. The two models (Maximum, Minimum) correspond to an upper and to a lower limit of particle number densities compatible with the in situ measurements, respectively.

Table 1

Parameters (see text) of the two Models used in Fig.2

region	Maximum - Model			Minimum - Model		
	$a/\mu m$	κ	n_o/cm^{-3}	$a/\mu m$	κ	n_o/cm^{-3}
A	0.008 to 0.16	2.7	$0.95 \cdot 10^{-12}$	0.008 to 0.16	2.7	$1.75 \cdot 10^{-13}$
B	0.16 to 28.8	2.0	$1.12 \cdot 10^{-14}$	0.40 to 21.4	2.5	$1.99 \cdot 10^{-15}$
C	28.8 to 339	4.33	$1.91 \cdot 10^{-17}$	21.4 to 339	4.33	$1.17 \cdot 10^{-17}$

The scattering function adopted for fig. 2 was a simple superposition of diffraction plus conservative, isotropic reflection (albedo W=1). Even with this high albedo the intensity produced by the minimum model is too low by a factor of 2 to 4 for $30^\circ \leq \varepsilon \leq 180^\circ$. On the other hand, the maximum model produces with $W = 1$ in this range of ε intensities higher than observed and approaches the observational values with somewhat lower ($W = 0.4$ to 0.6) values of the albedo. It also fits the zodiacal light fairly well in the inner regions ($\varepsilon < 30^\circ$). Therefore we conclude that the interplanetary particle number densities derived by in situ measurements are now in good agreement with the optical measurements.

The relative contribution of the different particle sizes to the zodiacal light raises some important aspects in interpretation. Up to now model computation based on Mie-theory implied a great fraction of small particles to produce positive polarization at the correct region of elongation. Such components were dielectric particles of submicron-size ($\bar{a} \simeq 0.1$ µm, Weinberg 1964) or somewhat larger ($\bar{a} \simeq 0.4$) absorbing particles or slightly absorbing particles of ~ 10 µm-size (see Giese 1973). If, however, the number densities of the Maximum-Model are adopted the contribution to the total brightness at $\varepsilon = 90^{\circ}$ is < 0.6 % for particles of $0.008\ \mu m \leq a \leq 0.16\ \mu m$ and 19 % for particles of $0.16 \leq a \leq 9.5\ \mu m$. Therefore the contribution of the submicron-size particles (region A of Table 1) is completely neglible. The largest particles ($a > 29 \mu m$) of the Maximum-Model (region C) still contribute 42 % of the total brightness.

Due to the considerable contribution of larger particles more information about the scattering function of irregular dust grains in the size range above $a \simeq 10\ \mu m$ is needed. Here Mie-theory is of limited use, not only because such computations are rather time consuming. For larger dielectric particles the approximation by spherical shapes (Mie-theory) produces extremely strong backscattering effects and bumps in polarization (see Giese 1963), such as haze bows,which are unrealistic for interplanetary dust particles. Microwave analog measurements, which simulate light scattering by practically dielectric, nonspherical particles corresponding to micron-size (Zerull 1975, Fig. 3 and 4) suggest much more isotropic scattering and rather neutral polarization outside the diffraction region of the scattering diagram.

For larger ($a \gtrsim 1.5\ \mu m$), sufficiently absorbing spheres Mie-theory can be approximated roughly by a simple superposition of diffraction plus Fresnel reflection (see Giese 1961). Microwave measurements (Zerull 1976, Fig. 6) suggest that also irregulary, absorbing particles produce strong positive polarization similar to Fresnel reflection.

In a qualitative way we conclude, that intensity and positive polarization observed in the zodiacal light can be produced by a mixture of irregular particles with an appropriate mixing ratio of dielectric and absorbing material without the need to fall back upon a large contribution due to particles of micron or even submicron size. There are, however, still problems to obtain quantitative agreement, especially with the observational position of the maximum of polarization. Analysis of the empirical scattering function as derived directly from zodiacal light measurements (Dumont 1975, Leinert et al. 1976) and further laboratory experiments are needed to achieve convincing quantitative models.

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