ORBITAL ELEMENTS OF MICROMETEOROIDS DETECTED BY THE HELIOS 1 SPACE PROBE IN THE INNER SOLAR SYSTEM

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The Helios Spacecraft is able to detect micrometeoroids along its orbit in the inner Solar System between 0.3 AU and 1 AU distance from the sun (Grün et al. 1977, Grün et al. 1979). Data of the first 6 orbits are presented here. 168 particles have been identified in such a way that their osculating orbital elements (here especially semimajor axis a, eccentricity e and inclination i) can be calculated. Detailed information on impact speed is available only up to about 50 km s^{-1} which corresponds to a lower mass limit of 10^{-11}g (Dietzel et al. 1973). So the detected micrometeoroids are divided into two groups below and above 10^{-11}g for each sensor. Table 1 gives the absolute number of dust particles in the different mass intervals.

Table 1 Identified particles of the first 6 orbits of Helios 1

	Sensor	
Mass (g)	South	Ecliptic
$< 10^{-11}$	73	29
$> 10^{-11}$	43	23

The particles in the observed mass ranges are influenced in their orbital motion by radiation pressure. Therefore mass-dependent models of radiation pressure were taken into account. The models used a mixture of materials in proportions to represent the optical properties of the zodiacal dust cloud according to Röser and Stauda (1978). One model includes absoring materials (graphite), the other has none. Above 10^{-11}g there is not a great difference

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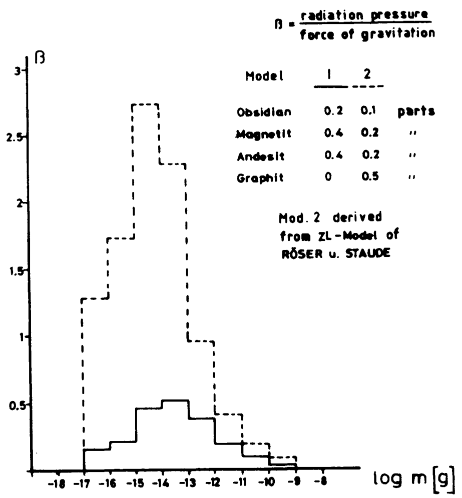

Figure 1 Mass dependent radiation-pressure models.

in the models so that the orbits of large particles are not affected by the choice of model. Depending on the velocity at the time of creation, β-values below 1 may be enough to blow particles out of the Solar System. From this point of view the two models may be considered as upper and lower limits of radiation pressure, until we know the detailed optical properties of the particles.

The uncertainties in impact speed and impact direction (due to the large viewing cones of the micrometeoroid sensors) forced us to calculate many possible dust velocities for each single particle (Schmidt and Grün 1979). Taking into account sensor intrinsic weighting factors for different impact directions we computed probability distributions for the osculating orbital elements. In Fig. 2 an example of the probability p for a single particle to be in a certain orbital element interval is given. Since particles on unbound (hyperbolic) orbits are leaving the Solar System, the probabilities for the different hyperbolic orbits are given as a sum (p_{hyp}). For particle no. 137 the total probability for hyperbolic orbits is 24% if ß = 0.4, whereas all possible orbits are bound for ß = 0.0. Radiation pressure shifts 1/a to lower, e to higher values, but does not affect inclination. 98% of the detected particles were on prograde orbits. Fig. 3 shows the probabilities for groups of particles normalized to unity. Larger particles are not so much affected by the two different models of radiation pressure. These particles are nearly all on bound orbits.

The mass range of the larger particles corresponds to those which make the major contribution to the observed zodiacal light. The smaller particles which are in size ranges that do not contribute to the zodiacal light have high probabilities to be on hyperbolic orbits leaving the Solar System on their first orbit. Table 2 gives detailed information about these hyperbolic micrometeoroids, which were divided into three groups for each sensor, depending on the direction the

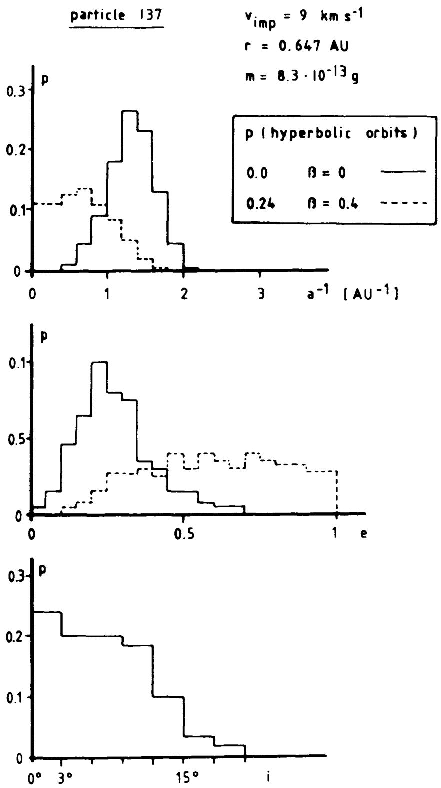

Figure 2 Probability distributions for a single particle.

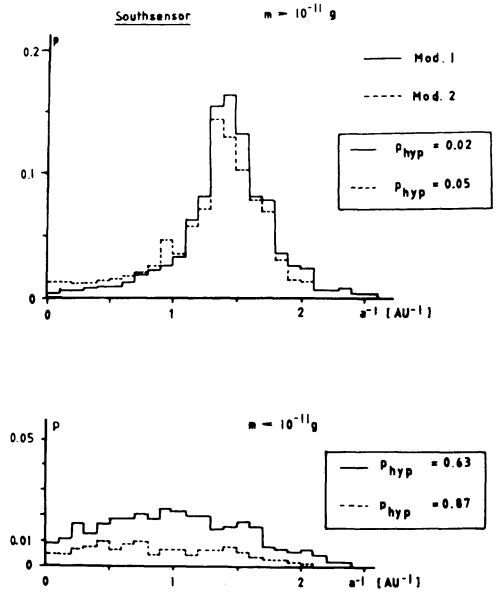

Figure 3 Probability distributions for groups of particles.

particles were going when they were detected. Under the above mentioned conditions of sensor characteristics and radiation pressure models, there were comparable numbers of particles travelling inward (toward the Sun) and outward. The difference in the counts for these two groups must be due to β-meteoroids produced inside the orbit of Helios. New results (Schwehm 1979) which show that melting and evaporation of dust grains near the sun is not a sufficient source for β-meteoroids, may explain the rather small number of β-meteoroids. A source for the incoming particles of small masses may be dust-dust collisions outside the orbit of Helios. The possible interstellar origin of these particles is doubtful due to the work of Morfill and Grün (1979), who concluded that the solar magnetic field may shield the inner Solar System from interstellar particles.

Table 2 Number of hyperbolic orbits

Southsensor	ß = 0	Mod. 1	Mod. 2
into the Solar System	8	11	17
out of the " "	7	21	26
detected close to perihelion	9	10	16
Eclipticsensor			
into the Solar System	0	1	9
out of the " "	2	5	11
detected close to perihelion	0	0	4

The results of this analysis suggest that at least two different groups of particles in the mass range of 10^{-6}g to 10^{-15}g exist, inferred from their dynamical behaviour. One group has masses greater than 10^{-11}g, moves on bound orbits and contributes to the zodiacal light, the other group consists of small grains with masses less than 10^{-11}g moving on hyperbolic orbits.

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SUMMARY OF DISCUSSION

The conclusion that most large particles are on bound orbits is in conflict with Fried's (1978 Astron. Astrophys. *68*, pp. 259-264) observation of higher orbital velocities seen in the Doppler shift of solar absorption lines in the zodiacal light. Although particle speed is determined by Helios only within a factor of two, this is still accurate enough in many cases to discriminate between bound and hyperbolic orbits. The high line-of-sight velocities implied by Fried's observations cannot be produced by any known forces.