COLLISIONAL BALANCE OF THE METEORITIC COMPLEX. E. Grün, H.A. Zook and H. Fechtig, MPI f. Kernphysik, Heidelberg, FRG.

Mutual collisions between meteoroids in the interplanetary meteoritic complex give rise to some interesting consequences which are here examined. From lunar crater statistics and satellite data, the size distribution and flux of micrometeoroids at 1 a.u. distance are derived. We evaluate the relative rates of destruction and production of grains by mutual collisions and the operation of other processes that determine the time stability of the interplanetary meteoritic population.

The size distribution of lunar microcraters by Morrison and Clanton (1) has been calibrated with respect to meteoroid masses (2) at an assumed impact speed of 20 km/s and a particle density of 2.5 g/cm^3. Absolute particle fluxes at 10^{-6} and 10^{-7}g were obtained from the Pegasus satellites (3,4) (see Figure 1). The resulting fluxes are slightly higher than the fluxes at 10^{-12} and 10^{-13}g measured by the HEOS-2 experiment (5,6). The latter measurements took into consideration the azimuthal distribution of impacts observed by Pioneer 8 and 9 (7). Most of the interplanetary meteoritic mass($\sim 4 \times 10^{-17}$ g/m^3 at 1 a.u.) is in particles of mass 10^{-6} to 10^{-4}g.

Using the size distribution obtained above, the rate of catastrophic collisions is calculated, taking into account the dependence of rupture energy upon particle size (8). The mass loss rate is greatest ($\sim 6 \times 10^{-29} g/m^3 s$) from catastrophic breakup of particles in the mass interval 10^{-4} to 10^{-2}g (cf. Figure 2). The catastrophic collision lifetimes range from $\sim 10^4$ to nearly 10^5 years at 1 a.u. for particles in the mass range 10^{-13} to 1g. Only for particles with $m \lesssim 10^{-9}$g are the Poynting-Robertson lifetimes comparable to, or less than, the collision lifetimes.

Fragment particles are produced by the collisions. Their mass distribution (c.f. Figure 2) is based on laboratory experiments that give the relationship between fragment, projectile and target masses (9). By comparison of the parent mass destroyed with the fragment mass generated in each mass interval the following conclusions can be drawn:

1. For masses $m \gtrsim 10^{-3}$g about 10 times more mass is destroyed than generated. Without continuous replenishment from a non-collisional source, meteoroids in the mass range 10^{-4} to 1 g would suffer depletion on a time scale of $\sim 10^4$ years.

2. Under steady state conditions, most particles with $m > 10^{-4}$ are "young", i.e. they have not been fragmented by collisions and their initial orbits are not much altered by radiation pressure drag. Meteor observations showing that many large meteors are concentrated in streams support this finding. Most mass has to be injected into the meteoritic complex by a source (e.g. comets) in the form of 10^{-4} to 1g particles.

3. In the mass range 10^{-7} to 10^{-4}g, interplanetary micrometeoroids are in approximate collisional equilibrium, i.e. about equal amounts of particles are removed from and introduced into a given mass interval per unit time.

4. At masses $m \lesssim 10^{-8}$g many more (factors of 10 to 100) particles are generated by collisions than are destroyed. Thus, these particles must be removed from the meteoritic complex by means other than collisions if time stability is maintained. Evolution under Poynting-Robertson drag and, more importantly, direct injection of particles into hyperbolic orbits under radiation pressure (β-meteoroids) cause the removal of these small particles.

We assume that all particle fragments in excess of those required to maintain steady state are injected into hyperbolic orbits and become β meteoroids. It is further assumed that the spatial dust density varies as $n \sim r^{-1.3}$ (10), the relative speed varies as $v \sim r^{-0.5}$, and that the size distribution does not change with r(r > 0.03 a.u.). Inside r = 0.03 a.u., the density is assumed to be zero.

With these assumptions it can be shown that the flux of β-meteoroids which are generated by collisions is a factor ∿ 100 below the flux required to produce the submicron- and micron-sized craters at the moon. Therefore, an additional source of small particles is required to provide the observed small impact craters on the moon. We suggest that impacts from high speed lunar ejecta are responsible for these microcraters.

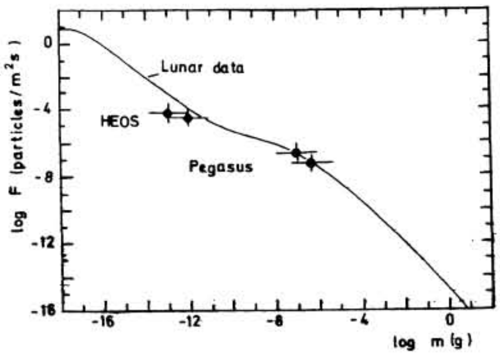

Fig. 1: Cumulative particle flux on a spinning (perpendicular to the ecliptic) flat plate at 1 a.u. from calibrated (2) lunar crater statisticts (1) and satellite data (3-6).

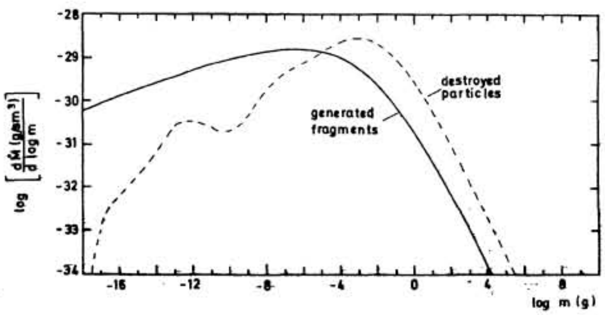

Fig. 2: Mass destroyed and fragments generated by collisions at 1 a.u.. A collision speed of 20 km/s has been assumed.

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Acknowledgement: This work was performed while one author (E.G.) was a Visiting Scientist at the Lunar and Planetary Institute.