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New calibration of the micrometeoroid flux on the Earth

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Abstract

The micrometeoritic flux on Earth derived by [5] from cratering data on the Long Duration Exposure Facility (LDEF) has to be revised in light of the new estimates of the impact velocity of particles and updated scaling laws for hypervelocity impacts derived from hydrocodes. We have obtained wew values of the impact velocity with a numerical approach that models the evolution of dust particles, of asteroidal and cometary origin, in the proximity of the Earth ([2]). The hydrocode iSALE is instead used to derive an appropriate scaling law relating the diameter of a crater on an aluminum alloy target, like the LDEF facility, to the projectile size. Different values of grain porosity and density are used depending on the origin of the dust grains.

1. Dependence of the meteoroid flux on the impact velocity

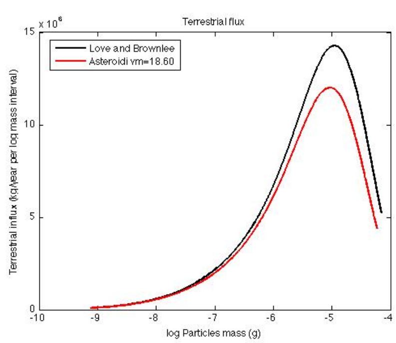

Figure 1: Mass of micrometeoroids accreted annualy on Earth as in [5] (black lines) and for an updated value of the impact velocity as derived in [2] (red line).

[5] estimated the mass flux of submillimiter particles impacting the Earth from cratering data on the surface of the LDEF satellite. To determine the size distribution of impactors they adopt an average meteoroid impact velocity of 16.9 km/s and an empirically determined formula relating the depth of a crater to the projectile diameter. An updated interpretation of the cratering data is however needed in light of recent developments of hydrocodes that allow specific predictions of the relation between crater and projectile size. In addition, via numerical integration of dust particle orbits from different sources, it is possible to give a better estimate of the average impact velocity on Earth. Different values of the impact velocity lead to a different estimate of the projectile size for each crater. The impactor kinetic energey depends in fact on v_i^2 and an increase of v implies a consistent reduction of the projectile mass.

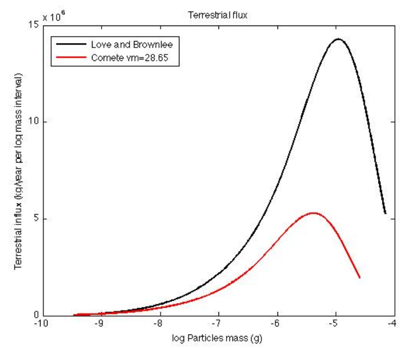

Figure 2: Same as in Fig.1 but for dust produced by Jupiter Family Comets. The impact velocity is much larges and the derived flux is almost 3 times smalles (red line).

In Fig.1 we show how the flux estimated by [5] changes once the more reliable value of 18.6 km/sec for the impact velocity of dust coming from the asteroid belt is adopted ([2]). The difference is much more striking when we assume that most of the dust collected at the Earth surface is of cometary origin as argued by [6] and [9]. The impact velocity in this case turns out to be 28.65 km/sec, as derived from numerical integration of dust with orbital elemets typical of Jupiter Family Comets. The same numerical model exploited in [2] has been used where all the planets, radiation pressure and Poynting-Robertson drag have been included. In Fig.2 the expected flux derived from LDEF is lower by almost a factor 3. This result has profund implications for the inferred flux of meteoroid on other solar system bodies when tuned on the Earth estimated flux.

2. New scaling law

The impact velocity is not the only important parameter in deriving the dust flux on Earth from cratering recors on LDEF, also the scaling law has a relevant part in the estimation process. We use the hydrocode iSALE ([1], [3], [10]) to derive a scaling law consistent with the physical conditions of the LDEF facility. This code is well validated with laboratory experiments and with other hydrocodes ([8]) and it can be successfully used to derive a reliable relation between the crater size and projectile diameter. The surface of the LDEF facility, where the craters analysed by [5] were recorded, is modeled in our hydrocode simulations as an "infinite"plane of aluminum alloy 6061-T6, for which we adopted the Johnson-Cook strength model ([7]) and the Tillotson equation of state (EoS). The projectiles are assumed to be micrometeoroids of basaltic composition, described by standard rock strength models ([4]) and by the ANEOS EoS.

Taking into account the different origin of micrometeoroids impacting the Earth different values of porosity and density must be considered. Dust from asteroids is expected to be more compact with a density of about 2.5 g/cm^3 and resembles carbonaceous chondritic meteorites. Cometary dust is possibly made of fluffly aggregates with higher porosity and similar to CI chondrites.

3. Discussion

Our methodology to derive from ihypervelocity impact cratering records reliable estimates of the projectile flux can be used in future missions with exposure facilities like that on LDEF. The scaling law may need some tuning if the layer is made of material other than aluminum alloy. The relative fraction of dust coming either from asteroids or from comets can be properly calibrated once additional research will be made, both on theoretical and experimental ground, to discriminate between these two sources.

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