

A NEW INTERPRETATION OF THE SIZE DISTRIBUTION OF MAIN-BELT ASTEROIDS. D. D. Durda, R. Greenberg, and R. Jedicke, Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson, AZ 85721.

The size distribution of the main-belt asteroids provides a strong constraint on models of the collisional history of the asteroid belt. The most important factor in determining the shape of the evolved size distribution is the dependence of the critical specific energy on target size. The critical specific energy, Q^* , is the energy per unit target mass required to fragment and disrupt a target asteroid, leaving a largest remnant with 50% the mass of the original target.

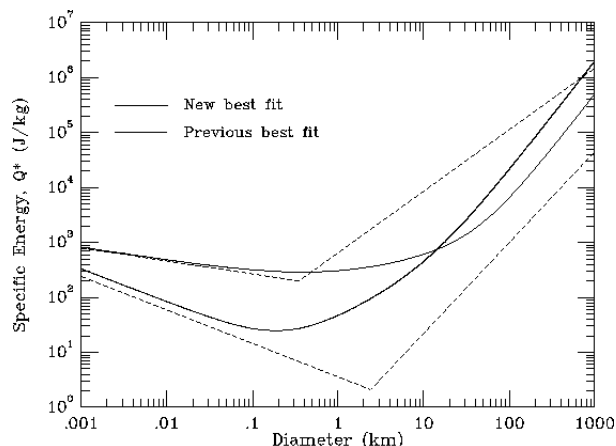
A number of studies have focused on determining how Q^* for asteroidal bodies scales with target size. Treatments of the size dependence of Q^* have generally been considered in two separate regimes: the strength-scaling regime, where the response of small targets to catastrophic impacts is governed by material strength, and the gravity-scaling regime, where the outcome of collisions is dominated by gravitational effects. Analytical models formulated for the strength-dominated regime are based on an assumed size distribution of flaws inherent in the target material and result in specific energies scaling as roughly $D^{-0.2}$ to $D^{-0.6}$, where D is the target diameter [1–4]. In the gravity-dominated regime Q^* increases with target size, scaling as roughly $D^{1.0}$ to $D^{2.0}$ as indicated by scaling relations and various hydrocode models [2, 5–7]. Considerable uncertainty remains in the precise dependence of Q^* on D in the two scaling regimes as well as the size at which gravitational effects begin to dominate over inherent material strength.

An alternative means of determining the size-strength scaling relation for asteroidal bodies utilizes the fact that the detailed dependence of Q^* on D translates directly into observational features in the evolved size distribution. Durda [8] showed that the power-law index of a collisionally evolved population is linearly dependent upon the slope index of the size-strength scaling relation and that abrupt changes in the dependence of Q^* on D can result in distinct kinks or humps in the size distribution. Given that the evolved size distributions generated by collisional models depend strongly (and understandably) upon the shape of the size-strength scaling law, Durda [8] (reported also in [9]) adjusted the strength law for asteroidal bodies to obtain a best fit to the then-accepted asteroid size distribution. The best fit strength law featured a very gradual, almost flat, transition between strength and gravity scaling at diameters of ~ 10 km and resulted in a modeled size distribution showing good agreement with the power-law small asteroid population derived from Palomar-Leiden Survey data. This result implied

that the well-known hump in the asteroid size distribution at ~ 100 km is directly due to the strengthening effects created by the transition between strength and gravity scaling at ~ 10 km. Similar results were obtained by Davis *et al.* [10] who examined the evolved size distributions produced by various published scaling laws.

The latest determination of the size distribution of 10 km-scale main-belt asteroids from Spacewatch data by Jedicke and Metcalfe [11], however, clearly shows that the small asteroid size distribution cannot be fit by a single power-law. Their results show a double hump structure to the size distribution, with a small hump in the ~ 2 – 20 km size range in addition to the previously known ~ 100 km hump. Motivated by this new determination of the main-belt size distribution and guided by results of recent hydrocode studies, we proceed as in Durda [8] and adjust the assumed shape of the scaling relation until we find one for which the final modeled population from our collisional model matches the observed main-belt size distribution. A successful match would be strong evidence that the corresponding size-strength scaling law is a good representation of the actual behavior of asteroids in catastrophic collisions.

Figure 1. Our best fit size-strength scaling relation is shown by the lower solid curve with a minimum near 200 m. The upper solid curved line is the previous best fit scaling law from Durda [8]. The region between the dashed lines represents the range of scaling relations published in references [1–7].



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Our best fit to the actual asteroid size distribution of Jedicke and Metcalfe [11] is obtained with the scaling law shown in Fig. 1. This scaling relation is well within the range of plausible critical specific energies

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and is consistent with the results of the latest hydrocode models indicating a transition to gravity scaling at smaller sizes than previously thought [6, 7, 12]. The resulting modeled size distribution is shown in Fig. 2 to agree well with the actual size distribution, reproducing the two-hump structure found by Jedicke and Metcalfe [11].

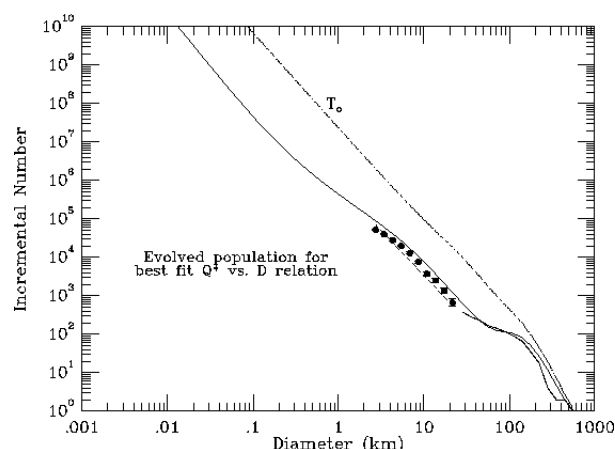


Figure 2. Our best fit to the observed size distribution of main-belt asteroids. The solid points are the Spacewatch data of Jedicke and Metcalfe [11]. The dashed line just below the Spacewatch data is the previous best estimate of the small asteroid population determined from Palomar-Leiden Survey data.

Our results show for the first time general agreement between the predictions of hydrocode models, the results of numerical collisional models, and the observed asteroid size distribution, and lead to a new interpretation of the shape of the main-belt asteroid

size distribution:

1) We find a strength scaling law which, when used within our numerical collisional model, gives good agreement with the two-hump structure observed in the actual size distribution of main-belt asteroids.

2) The hump in the size distribution between ~2–20 km is a primary hump due to the transition from strength scaling to gravity scaling for asteroids larger than ~200 m. The well-known hump observed in the asteroid size distribution at ~50–200 km is a secondary hump resulting from wave-like structure induced in the size distribution by the ~2–20 km primary hump.

3) The strength scaling law implied by this work is most consistent in the gravity scaling regime with the hydrocode models of Nolan [12] and Melosh and Ryan [7] and the strength scaling predictions of Davis *et al.* [5].

Combined with results of continued laboratory impact experiments and further refinements to hydrocode models, our results should lead to a better understanding of the physical structure of asteroids of all sizes.

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