Exploring the collisional evolution of the asteroid belt

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The asteroid belt is a remnant of planet-formation processes. By modeling its collisional and dynamical history, and linking the results to constraints, we can probe how the planets and small bodies formed and evolved. Some key model constraints are: (i) The wavy shape of the main-belt size distribution (SFD), with inflection points near 100-km, 10–20-km, 1 to a few km, and ∼0.1-km diameter; (ii) The number of asteroid families created by the catastrophic breakup of large asteroid bodies over the last ~ 4 Gy, with the number of disrupted $D > 100$ km bodies as small as ∼20 or as large as 60; (iii) the flux of small asteroids derived from the main belt that have struck the Moon over the last 3.5 Ga — crater SFDs on lunar terrains with known ages suggest the $D < 0.1$ km projectile population has not varied appreciably over this interval; (iv) Vesta has an intact basaltic crust with two very large basins, but only two, on its surface.

Fits to these parameters allow us to predict the shape of the initial main-belt SFD after accretion and the approximate asteroid disruption scaling law, with the latter consistent with numerical hydrocode simulations. Overall, we find that the asteroid belt probably experienced the equivalent of ∼6–10 Gy of comminution over its history. This value may seem strange, considering the solar system is only 4.56 Gy old. One way to interpret it is that the main belt once had more mass that was eliminated by early dynamical processes between 4–4.56 Ga. This would allow for more early grinding, and it would suggest the main belt's wavy-shaped SFD is a "fossil" from a more violent early epoch. Simulations suggest that most $D > 100$ km bodies have been significantly battered, but only a fraction have been catastrophically disrupted. Conversely, most small asteroids today are byproducts of fragmentation events. These results are consistent with growing evidence that most of the prominent meteorite classes were produced by young asteroid families.

The big question is how to use what we know to determine the main belt's original size and state. This work is ongoing, but dynamical models hint at many possibilities, including both the late arrival and late removal of material from the main belt. In addition, no model has yet properly accounted for the bombardment of the primordial main belt by leftover planetesimals in the terrestrial planet region. It is also possible to use additional constraints, such as the apparent paucity of Vesta-like or V-type objects in the outer main belt, to argue that the primordial main belt at best only 3–4 its current mass at its start. In our talk, we will review what is known, what has been predicted, and some intriguing directions for the future.