Reply to Boslough et al.: Decades of comet research counter their claims

Bosloughet al. (1) offer no alternate explanation for ~10 million tonnes of Younger Dryas spherules recovered from 18 sites across ~50 million square kilometers of North America, Europe, and the Middle East (2). In addition, the authors claim that our hypothesis "demonstrates a misunderstanding of comets." However, the misunderstanding is theirs alone, because the model they criticize is their own creation and not the one we adopt, which derives from a substantial body of comet literature (e.g., ref. 3).

Most Earth-crossing comets arrive from the Oort cloud and the transneptunian region by way of the centaur population, an unstable reservoir orbiting between the giant planets that feeds the Jupiter family and Earth-crossing populations. From the size distribution of centaurs, as revealed by the Near-Earth Object Wide-field Infrared Survey Explorer space telescope (4), we find that there should be ~30 centaurs >100 km in diameter with an average semimajor axis of ≤18 astronomical units (au) at any time. About half of them become Jupiter-crossing within 500,000 y, and 1 in 10 enter Earth-crossing, short-period orbits in the ecliptic plane, usually repeatedly (5). About one such entry occurs per 25,000 y, with a mean duration ~2,000 y, although comets that reach sub-Jovian orbits achieve relative stability and much longer dynamical lifetimes. It is, therefore, not surprising to find the fossil remains of a large, recent, short-period comet in the near-Earth environment. There is such a system, comprised of about 15 correlated meteor streams containing some of the larger near-Earth "asteroids" (~2–5 km wide), as well as comet Encke at ~5 km in diameter. The whole system is embedded in a broad swath of meteoroidal material dominating the zodiacal cloud. The mass and dispersion of this material indicates that the progenitor comet was initially ~100 km across and began to break up at least 20,000 y ago (6). This system's mass is far larger than the entire current near-Earth asteroid system.

Most meteor streams originate from discrete fragmentation events rather than gradual sublimation, and the substreams of the complex show that the progenitor comet also followed this route. Breakups tend to happen just after perihelion passage, yielding clusters of fragments with, at 1 au, about 10,000 times the cross-sectional area of the Earth. Hundreds of such clusters (~10^{18} g) may be temporarily created over the lifetime of the comet. Passages through one or two are reasonably probable events, and are capable of yielding Younger Dryas boundary-like phenomena (3); no "exquisite timing" is required, as claimed by Boslough et al. (1).

Fragmentation yields a power law distribution of mass with population index ~1.7, from which interception of 10^{14} g at 30 km/s may yield several impactors with energies up to 5,000 megatons, fully adequate for surface melting, contrary to claims by ref. 1. Current impact hazard assessments predict one such impact with recurrence time in excess of 50,000 y, but these assessments are based on the erroneous assumption of a steady-state comet population. The occasional injection of giant, short-period comets negates this assumption over timescales relevant to civilization.

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The authors declare no conflict of interest.

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