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Probabilistic Characterization of Tunguska-scale Asteroid Airbursts and Impact Frequencies

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Abstract

Asteroids exhibit a diverse range of properties, with large variations of densities, strengths, and structural compositions. These varied properties, along with different entry velocities and angles, could greatly affect the amount of damage an asteroid of a given size could cause if it strikes the Earth. The 1908 Tunguska event provides a rare source of evidence for characterizing these effects, and many studies have attempted to infer the object's size, properties, or impact characteristics. However, most such studies only consider small subset of cases, employing selective assumptions of representative properties.

In this study, we used our Probabilistic Asteroid Impact Risk (PAIR) model [1] to more broadly characterize the range and relative likelihood of asteroid properties that could yield Tunguska-scale threats [2], and to evaluate the effects of probabilistic asteroid property distributions on estimates of impact frequencies for these size ranges [3].

In the first part of the study, we modeled the entry, airburst, and ground damage from 50 million Tunguska-scale asteroid impacts, which were sampled from probabilistic distributions that represent current knowledge of asteroid properties and size frequencies. Results demonstrate that a broad range of asteroid characteristics can produce Tunguska-like airburst events and emphasize the relative probabilities among them. A key finding is that Tunguska-scale ground damage is more likely to be caused by asteroids on the larger end of estimated size and energy ranges, despite their lower expected impact frequency. Even when relative size frequencies are accounted for, the greater damage potential of larger objects outweighs their rarity, while the low damage potential of small objects counteracts their frequency.

In the second part of the study, we also applied probabilistic asteroid property distributions to evaluate the average expected frequencies of Earth impacts as a function of size, mass, energy, and resulting blast damage. The results demonstrate that accounting for realistic distributions of asteroid properties can significantly increase expected frequencies for Tunguska-scale impacts compared to estimates based on mean albedo, density, and velocity assumptions. These higher impact frequencies in turn increase the estimated risks associated with these asteroid sizes.

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