

SOURCE ENERGY ESTIMATION OF TON TNT-SCALE IMPACTS BASED ON WELL-KNOWN METEORITE FALLS

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Introduction: Cosmic objects are impacting the Earth's atmosphere on a daily basis. Due to their small size, these meteoroids cannot be seen before interacting with the air particles. Thus, to better constrain the size of an impactor, we need calibrated multi-detector observations of meteoroid impacts into our atmosphere. These recording instruments range from cameras and radio antennas [1], to detections of meteoroid airwaves using infrasound arrays, and seismic detectors, which measure the signal produced by airwave-to-ground coupling of large events.

Purpose: In this study we explore several techniques of measuring the pre-atmospheric mass of meteoroids with well-known trajectory (also a subject of meteorite recoveries), at the source of ton TNT-scale atmospheric impacts [2]. On this scale, the impact is less likely to cause an airwave signal detectable on multiple specialized stations, or the estimation methods carry high uncertainty [e.g. 3, 4], hence, their mass is poorly constrained.

The bolides: To compare the reliability of the energy estimation methods, first, the meteoroid-derived measurements were collected from the literature. The resulted list pointed to the object's radiation as the most common measured property of the event. Thus, the analysis focused on the optical energy signature of the objects. Most of the bolides did not have their total radiated energy estimated, hence, this was obtained based on the published light curve. Next, their kinetic energy was computed based on given estimates of velocity and mass.

Results & Discussion: To derive the empirical relation, a best fit was obtained from the source energy vs the optical energy (Fig. 1). Although the radiated light and mass would ideally be modelled as a function of velocity, the obtained relation [2] shows a good correlation between the object's kinetic energy at entry and its capability of radiating light during deceleration, regardless of the object's fragmentation and ablation profile.

Conclusion & Implications: The result represents a (more accurate) continuation of the relation presented by [5], towards more frequent, lower scale impactors. The applicability of this relation is not limited to cameras. A better estimate of the radiated light can be obtained with calibrated radiometers e.g., [6] or from the next generation lightning mappers [7]. Their relative luminosity is not affected by clouds, and can be coupled with the trajectory triangulation obtained by the currently expanding ground-based fireball networks e.g., [1], [8], [9], etc. to compute the object's mass. This, in turn will help to cross-calibrate the methods, which can be further used to constrain the size-frequency distribution of impacts, thus, estimating the mass of objects endangering the rapidly increasing civilian infrastructure surrounding the Earth.

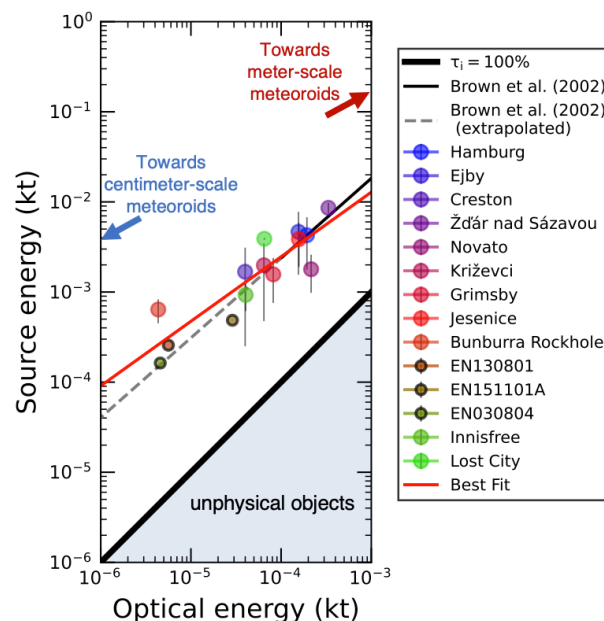


Figure 1. The source energy vs radiated energy correspondence for the well-known list of bolides. The thick line represents a luminous efficiency of 100%. The relation presented by [5] is extrapolated to this low energy regime using a dotted line. The red line represents the best fit line thorough the data.

References: [1] Colas F. et al. (2020) *Astronomy & Astrophysics* 644:A53. [2] Anghel S. et al. (2021a) *Monthly Notices of the Royal Astronomical Society* 508:5716. [3] Edwards W. N. et al. (2006) *Journal of Atmospheric and Solar-Terrestrial Physics* 68:1136. [4] Ens T. A. et al. (2012) *Journal of Atmospheric and Solar-Terrestrial Physics* 80:208. [5] Brown P. G. et al. (2002) *Nature* 420:294. [6] Rault J. L. and Colas F. (2019) *arXiv*: 1911:04290. [7] Stuhlmann R. et al. (2005) *Advances in Space Research* 36:975. [8] Anghel S. et al. (2021b) in *LPI Contributions Vol. 84*, Abstract #6027. [9] Vida D. et al. (2021) *Monthly Notices of the Royal Astronomical Society* 506:5046.