Hypervelocity Airburst Shower Formation of the Pica Glass, Atacama Desert, Chile

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Abstract

The recently discovered Pica Glass in the Atacama Desert, Chile (Schultz et al., 2021) requires rapid heating and quenching of surface materials by multiple airburst fireballs. Based on the surviving mineral assemblages from the object, the most likely scenario involves cascading fragmentation of a comet that broke up upon low-angle entry into the atmosphere. Modeled low-altitude airbursts from six fragments of a single 120-m diameter comet generated separate airbursts in roughly aligned and discrete glass sites that spanned more than 70 km. This scenario is not a unique solution; there are tradeoffs among speed, size, strength, and height of burst. The Pica Glass, because of its young age, provides useful ground truth for airburst simulations in support of planetary defense risk assessment. Computational shock physics models demonstrate that multiple discrete low-altitude airbursts from a small comet that fragmented upon low-angle entry into the atmosphere is compatible with the distribution and extent of the Pica Glass. Such a scenario has a sufficiently high probability that it is compatible with the young age of the glass, and is also relevant to airburst risk assessment for planetary defense.

Single airburst/surface interaction

The most probable asteroid entry elevation angle is 45° and the best model-based estimate for the 1908 Tunguska asteroid is 35° (Boslough & Crawford, 1997). However, there is no evidence that the hot vapor jet at Tunguska reached the surface, suggesting that it was a small object (~40 m diameter and ~5 Mt kinetic yield). A larger object would explode at lower altitude and contain enough mass and momentum for the high-temperature jet to descend to the surface. An object entering at that angle, however, would not melt the surface at widely separated locations. The Libyan Desert Glass probably formed by this mechanism (Boslough & Crawford, 2008) but has had 29 million years to be transported over the large area which it now occupies.

Two types of low-altitude airburst

Differentiation between a high-velocity fireball and a low-altitude airburst is not straightforward. A high-velocity fireball either stops before it reaches the surface or descends to and interacts with the surface. A low-altitude airburst is defined as an object entering the atmosphere at an altitude of less than 10 km and exploding within 10 km of the surface.

Summary

Computational shock physics models demonstrate that multiple discrete low-altitude airbursts from a small comet that fragmented upon low-altitude entry into the atmosphere is compatible with the distribution and extent of the Pica Glass. Such a scenario has a sufficiently high probability that it is compatible with the young age of the glass, and provides insight for the potential risks from low-altitude airbursts.