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Comparing Experimental and Numerical Studies of the Impact Flash: Implications for Impact Melt Generation

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Abstract

Laboratory impact experiments using non-volatile, particulate targets produce long-duration flashes, a result of thermal emissions generated by heated and melted materials [1-3]. These experiments have been used to assess the effects of initial conditions, in particular velocity and impact angle, on the observed impact flash evolution [4-5]. Numerical simulations carried out using CTH with modified equations of state will be validated with the experimental data. The combination of the experimental and numerical results will be used to predict the appearance of the impact flash at planetary scales and to address impact melt generation at various impact velocity and size scales.

1. Introduction

Due to projectile size and velocity limitations in the laboratory, experiments cannot completely simulate large-scale impacts. Experiments, however, capture complex interactions at all scales and provide a benchmark for computational simulations. Computational hydrocodes provide unprecedented insights into impact cratering and create impressive simulations of the cratering process. These numerical models can simulate impacts at all scales; however, complications include the difficulty of tracking multiple thermal sources, opacities, available equations of state for the materials involved, and assumptions made to simplify the calculations.

A multi-faceted approach to exploring the impact flash is therefore necessary. Relationships between initial conditions and the flash evolution have been derived through experimental impacts performed using the NASA Ames Vertical Gun Range. These results will be used to modify and calibrate numerical calculations created using the CTH hydrocode. Combining the experiments and numerical calculations will allow us to simulate planetary-scale impacts and to use these simulations to explore the source of the impact flash emissions and the generation of impact melt.

2. Experimental Impacts

Hypervelocity impact experiments were performed using the two-stage light gas gun at the NASA Ames Vertical Gun Range. Pyrex projectiles 6.35 mm in diameter impacted pumice powder targets under near-vacuum conditions (< 0.5 Torr) at angles from 90º (vertical) to 15º. Impact velocities ranged from 1.6 to 5.2 km/s. The predominantly silicate compositions of Pyrex and pumice minimize the production of atomic and molecular emissions in the visible wavelength range and enhance the generation of thermal emissions, which are of primary interest for this study.

Two photodiode systems [3] positioned above the target chamber recorded the visible and near-infrared light output every 100 ns for a total of 2 ms. The field of view of each photodiode was large enough to ensure that all radiating sources would remain observable over the recorded time interval. Two high-speed Shimadzu cameras also recorded the impact flash, from positions above and to the side of the impact chamber. These cameras acquired data at 10^6 fps and 500,000 fps, respectively, both with 200 ns exposure times.

An example impact flash light curve for a 30º impact is shown in Figure 1. Such light curves generally exhibit three common components: (1) an early-time spike (multiple spikes for 30º impacts), (2) a broad intensity peak, and (3) a long decay signal. Each component represents the effect of multiple processes and depends on initial impact conditions. In these experiments, the impact flash results primarily from hot material located within the transient crater cavity [4]. The impact angle affects the shape of the early-time transient crater, which in turn influences the exposure of the radiating source. The intensity peak magnitude and timing are related to the horizontal or vertical components of velocity. The delayed rise to the intensity peak is primarily caused by the growth of the radiating source [4].

Changes exhibited in the early-time spike feature are signs of changes in the interaction and coupling of the projectile and target. As impact velocity decreases, the projectile is less damaged, the projectile and target interact for a longer length of time, and friction becomes more important [e.g., 6]. At higher velocities, the projectile is broken into multiple hot fragments that radiate and scour across the transient crater floor. Planetary scale hypervelocity impacts into typical regolith-like substrates should generate long-lived thermal signals, the extent of which is strongly correlated to the strength of the projectile.

3. Numerical Impacts

We plan to perform numerical calculations to model the impact flash. These computations will simulate the conditions examined in the experiments (velocity, size, impact angle, materials). Numerical calculations will be performed using CTH, a shock-physics computational hydrocode [7]. It can be used along with equation of state packages (such as ANEOS or SESAME) to produce two- and three-dimensional simulations of vertical and oblique impacts.

The numerical calculations will start with two-dimensional, 90º impacts. After these results are reproduced and calibrated, we will move on to three-dimensional simulations and oblique impacts. The early-time luminous spike (see Figure 1) that was observed in previous studies [e.g., 2] is caused by the moment of first contact between the projectile and the target. Its detection during Pyrex/pumice powder impacts is due mainly to the use of transparent projectiles. The spike therefore provides a means to observe the conditions at the interface between the projectile and the target, which is important when comparing experimental data with CTH results in order to properly calibrate the code and to have confidence in its reproduction of the experimental results. Once this confidence in the CTH and signature model results is achieved, we can begin to approach extrapolations to larger-scale impacts.

As impact velocities increase, temperatures become hotter and more material is vaporized; however, there will always be proportionally more material melted than vaporized [8]. The experiments and the corresponding CTH models will allow us to estimate the amount of melt produced during these impacts based on the observed and calculated material temperatures; therefore, we can evaluate the importance of the melt contribution to the impact flash at varying velocities.

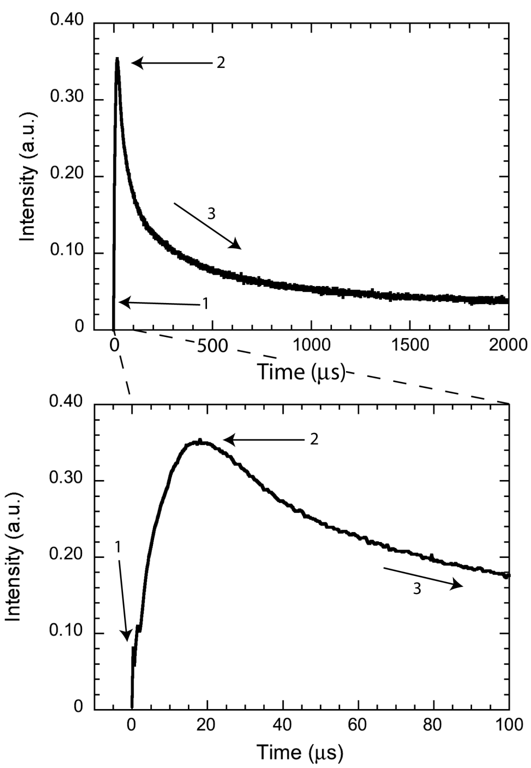

Figure 1: Plot of the light intensity evolution of (a) the first 2 ms and (b) the first 100 µs of a 30º, 6.35-mm Pyrex/pumice powder impact at 5.96 km/s. Three main components can be seen: (1) an early-time spike; (2) a broad intensity peak that dominates the signal; and (3) a long-lasting decay signal.

References

[1] Ernst, C. M. and Schultz, P. H.: *Icarus*, 190, 334-344, 2007. [2] Ernst, C. M. and Schultz, P. H.: *LPS* XXXIII, #1782, 2002. [3] Ernst, C. M. and Schultz, P. H.: *LPS* XXXV, #1721, 2004. [4] Ernst, C. M. et al.: *LPS* XLI, #1381, 2010. [5] Ernst, C. M. et al.: *LPS* XLII, #2299, 2011. [6] Barnouin-Jha, O. S. et al.: *Icarus,* 188, 506-521, 2007. [7] McGlaun, J. M. et al.: *Int. J. Impact Eng.,* 10, 351-360, 1990. [8] O'Keefe, J. D. and Ahrens, T. J.: *8th Lunar Sci. Conference Proc.*, 3357-3374.