Appearance of the Impact Flash in Meteorite Disruption Experiments

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Introduction: Studies of the optical flash that occurs in a hypervelocity impact have been done for some time [1, 2, 3], however, most of these have concentrated on results applying to space debris or missile defense. Our lab has observed the flash and occasionally made casual observations, but has done no concentrated studies on this flash. Terrestrial and meteoritic materials have been impacted for a number of years using the NASA Ames Vertical Gun Range. We have reported on other aspects of these experiments, including the energy of impact [4] and the mass-frequency distribution of the ejecta [5]. Herein we report on a preliminary examination of the flash as impacts are made into a variety of geological materials.

Experimental Setup: Samples are hung from a nylon line in a near vacuum and then impacted with 1/16" or 1/8" Al projectiles moving between 4 and 5.9 km/sec (Figure 1). The impacts are imaged using Shimadzu HyperVision HPV-1 cameras at 250,000 fps as well as a combination of Phantom Color V10, V12.1 and V2512 cameras at frame rates ranging from 1900 to 71000 fps.

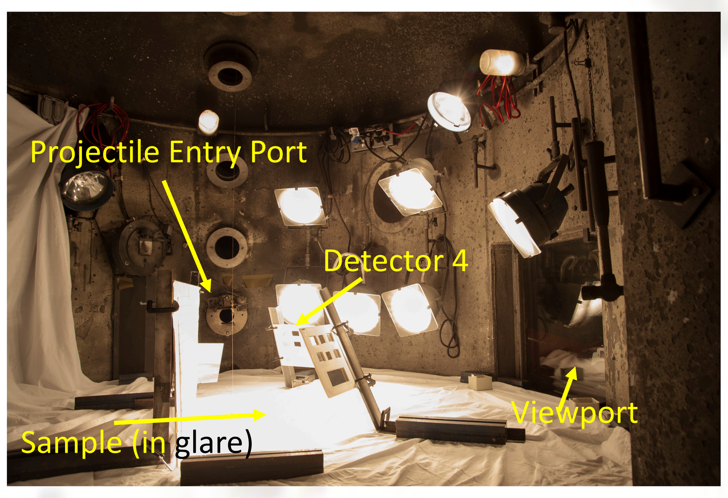

Figure 1: The interior of the AVGR chamber showing a typical setup. Two to four passive detectors were located around the sample. Each passive detector was located ~50 cm from the center of the target. Cameras were located in the viewing window to the right of the image, as well as in an overhead port.

Results and Discussion: A combination of terrestrial hydrated samples and various classes of meteorites, including artificially hydrated CI simulant materials, were measured (Figure 2). In general, it was observed that the initial flash for hydrated materials was smaller and more confined in shape, and that the entire flash sequence was shorter than for nonhydrated materials. Smaller flashes tended to be shaded with yellow or pink, while bigger flashes were haloed with blue. There is a concern about the timing of the flash with the video timing (Figure 3). An interesting observation was the development of brightness before the actual impact. This is clearly demonstrated in imagery using the Shimadzu camera at 250 K fps where the impactor can be seen for several frames before the impact (Figure 4). The results were relatively consistent across multiple impacts on different samples of the same material (Figure 5). There did not seem to be a correlation with impactor size or speed, the size of the target or whether the resulting impact resulted in disruption of the sample or not (Figure 6). In general, the results improved with faster camera frame rates that allowed more consistent timing in measuring the flash.

Figure 2. The range of samples investigated in the past several years. The flash is difficult to see in the older imagery (H5 and L6 – 2005, CM2 – 2007), but can be seen and measured. The general trend of a bigger, bluer flash in the ordinary chondrites and the iron fading to a smaller and yellower flash in the more hydrated materials is evident.

Figure 3. The time of impact for the same sample and the same shot, but from the perspective of the different cameras in the chamber. The left two images were a side and overhead view using the Shimadzu camera. The center image was a side view using a Phantom V12.1 and the right two images used a Phantom V2512. Although all of the slower cameras caught the large flash typical of an ordinary chondrite, the faster imagery shows an initial smaller flash that may be an artifact of the impact process (See Figure 4.)

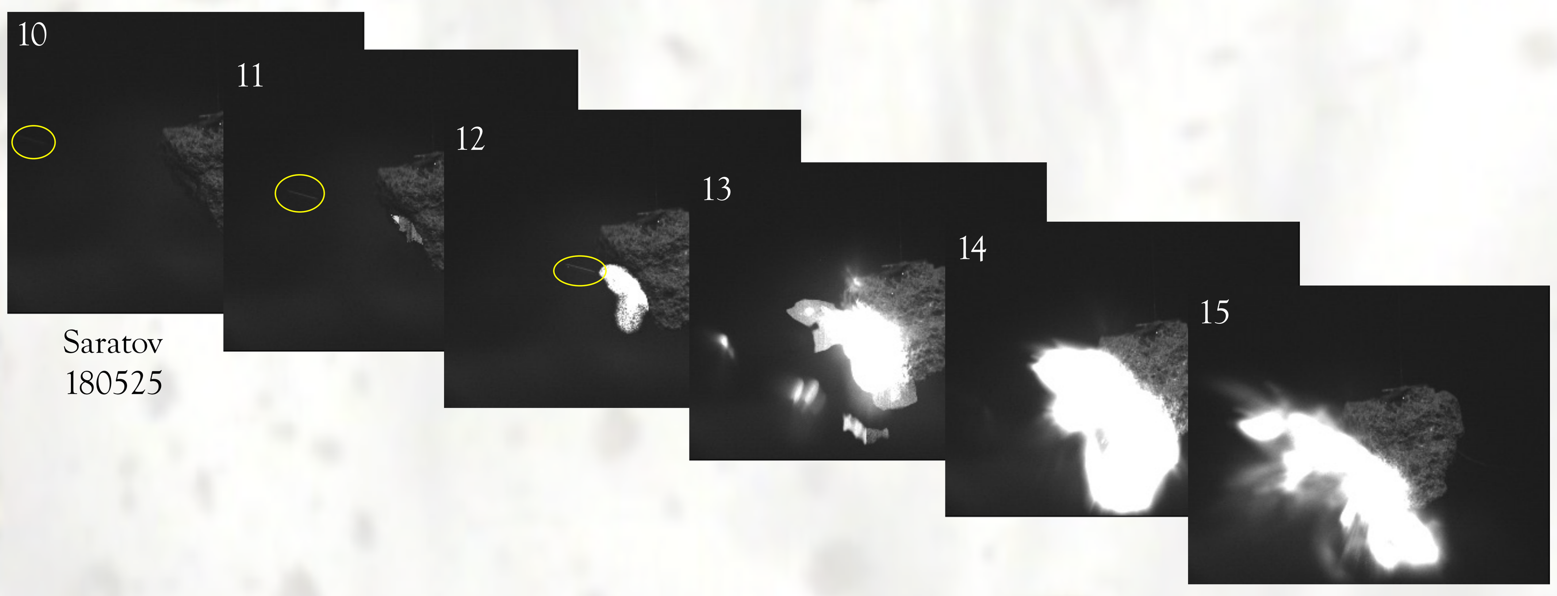

Figure 4. The sequence of the impact process using the Shimadzu camera at 250k fps. The projectile (1/16" aluminum pellet at 4.95 km/s) can be seen in three frames before the impact (10, 11 and 12). Discharge is observed from the crater site before the impact that can be significantly bright. After the impact (Fr 13), the typical flare is observed that then grows (Fr 14) and then detaches (Fr 15) as the debris cone moves out.

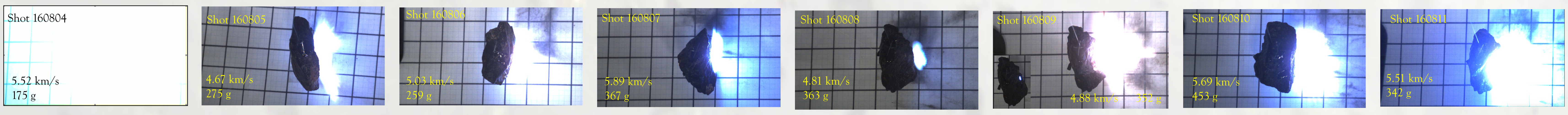

Figure 5. In order to create a reasonable data set for other studies [4], multiple shots were made of the same material. The concern about the frame rate is shown above, but it can be seen that for the most part different samples of the same meteorite (NWA 4502 is shown here) exhibit similar behavior. The inset in shot 9 shows the first flash when the camera happened to image in a very early stage of the process. All the shots were done with 1/16" Al pellets. All of the shots were cratering shots with the exception of 10 which seems to have hit a weathering layer and broke into three pieces.

Table I. Summary of observations on impact flash for the materials studied to date.

Sample	Number of Shots	Impact Speed (km/sec)	Target Size (grams)	Flash to Sample Size Ratio	Flash Shape	Flash Color
Carbonate	1	4.56	294	0.28 ± 0.11	Ball	White/pink
Montmorillonite	4	4.44 – 4.57	206 - 265	0.06 ± 0.04	Ball	White/yellow-pink
Serpentine	3	4.21 – 4.38	62 - 105	0.3.6 ± 0.42	Ball	White/blue
Hydrated NWA 4502	6	4.44 – 5.48	113 – 3.49	0.79 ± 0.1.4	Ball/Flare	White/yellow
Hydrated NWA 869	10	4.01-5.195.08	21 - 411	0.89 ± 0.66	Ball	White/yellow-pink
NWA 4502	14	4.11 – 5.89	82 - 453	2.7 ± 3.5	Flare/flash	Blue/white
NWA 869	6	4.06 – 5.35	132 - 216	0.77 ± 0.53	Flare/flash	Blue/white
Ordinary Chondrite (H, L)	8	4.18 – 5.21	51 - 113	1.7 ± 2.1	Flare/flash	Blue/white
Carbonaceous Chondrite (CM)	4	NA*	NA*	6.3 ± 7.9	Flash	White
CI Simulant	1	5.39	263	0.10 ± 0.01	Ball	White/yellow
Iron	4	4.35 – 5.71	84	6.6 ± 9.1	Flare/flash	White/yellow

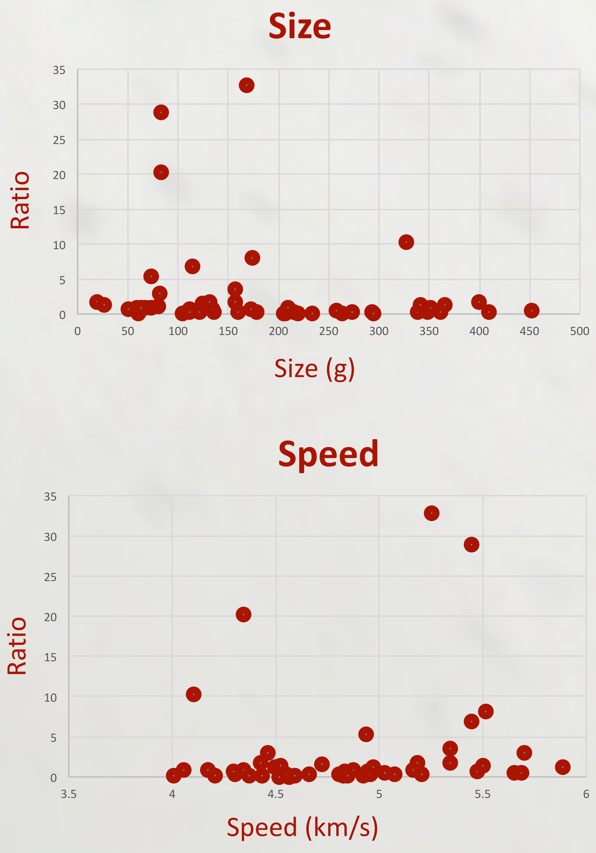

Figure 6. Correlations between measured parameters was investigated and there seemed to be no trends. Shown are the speed and the sample size versus the flash ratio.

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References: [1] Eichorn, G. (1975) *Planet. Space Sci.* 23:1519-1525. [2] Lawrence, R.J. et al. (2006) *Intl. J. Imp. Engr.* 33:353-363. [3] Goel, A. et al. (2015) *Intl. J. Imp. Engr.* 84:54-63. [4] Flynn, G.J. et al. (2017) *Planet. Space Sci.* 164:91-105. [5] Flynn, G.J. et al. (2009) *Planet. Space Sci.* 57:119-126.