EFFECTS OF VIEW ORIENTATION ON IMPACT FLASH OBSERVATIONS: IMPLICATIONS FOR LUNAR IMPACTS.

C. M. Ernst and P. H. Schultz, Brown University, Department of Geological Sciences, Box 1846, Providence, RI 02912 (Carolyn_Ernst@brown.edu).

Introduction: Recent experimental impact flash studies have assessed the effects of initial conditions on the resulting light intensity evolution for impacts into non-volatile, particulate targets [1-3]. The observations were all made from a location above the impact point. Due to the geometry of a forming crater, a lower-angle view orientation should decrease the observed flash intensity since portions of the radiating material will be hidden by the walls of the transient crater and by the expanding ejecta. Here, we assess the effects of the view orientation on the observed impact flash for both vertical and oblique impacts. Comparing the flash intensity and evolution from different view orientations also provides a method to examine the spatial distribution of the radiating source material.

Experiments: In order to assess view orientation effects, a series of laboratory experiments was performed at the NASA Ames Vertical Gun Range (AVGR). Pyrex projectiles (6.35 mm in diameter) impacted pumice powder targets at angles of 90º (vertical), 45º, and 30º. The projectiles were launched at velocities between 5.10 and 5.40 km/s under near-vacuum conditions (<0.5 Torr).

A photodiode with a spectral range of 350-1100 nm recorded the time-resolved light intensity of each flash up to a maximum time of 1 ms after impact. The photodiode had two observation positions, "top view" (A) and "side view" (B), as indicated in Figure 1. The top view position is located uprange and slightly to one side of the impactor trajectory, elevated 75º from horizontal. The side view position is located perpendicular to the impactor trajectory and elevated 15º from horizontal. Because the same instrument made both the top and side view measurements, data from two separate impacts compose each pair of observations.

Results: Comparisons between the top and side view intensity curves show that the flash appears significantly fainter when observed from the side view (Fig. 2). Over the entire 1 ms observed, the side view intensity never matches the level of the top view signal. Because the most of the observed signals decay steadily after ~50 µs, the light curves are only displayed out to 150 µs in order to better resolve the early-time features.

The initial early-time spike that is prominent in the top view is fainter, although still quite visible, in all side view cases. Since the spike occurs at the first contact of the projectile and the target [4], it is observable both from above and from the side because the projectile has not yet penetrated into the target.

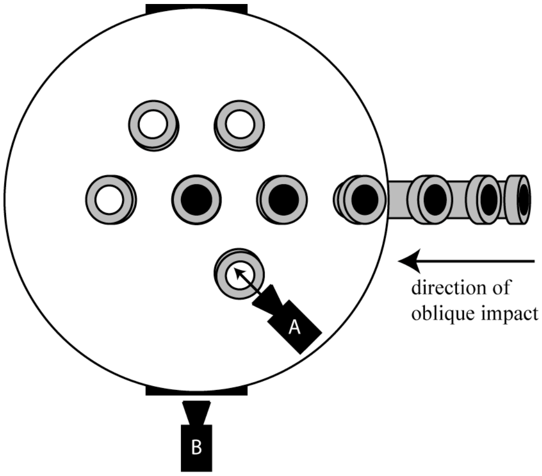

Figure 1. Illustration of the AVGR target chamber from above. The photodiode positions, top view (A) and side view (B), are indicated. Oblique impact trajectories come from the right of the image. The grey ports with white circles represent window ports, and the grey ports with black circles represent projectile entrance ports.

There is a clear difference between the total intensity (and thus the total luminous efficiency [3]) of the top versus side view observations. The side view exhibits the biggest disparity from the corresponding top view for the 90º impact (Fig. 2a). The total intensity out to 150 µs appears 9 times fainter from the side view. When integrating out to 1 ms, the difference is lower though still significant (the difference drops from 9 to ~6 times less). In the 90º case, the secondary rise to the broad intensity peak is not observed. Instead, the spike is followed by an elevated, though featureless, signal, implying that the radiation source causing the secondary intensity peak is not visible from the side view position.

For the oblique impacts (45º and 30º, Fig. 2b,c) the side view signals are also significantly fainter than their top view counterparts; however, in the oblique cases the top and side view light curves exhibit similar, though more subtle, post-spike characteristics. Interestingly, the timing of the secondary intensity peak is the same for both 45º impact views, but for the 30º impact the side view signal peaks while the top view signal continues to rise. The differences in intensity from the side to the top views are 6 times and 3 times less for the 45º and 30º cases respectively. The intensity seen from the side is always significantly less than the intensity from the top, and there is a non-negligible impact angle effect.

The observed angular differences in the side view observations can be attributed to transient crater formation and downrange momentum. A transient crater is deepest and narrowest during a 90° impact; most of the radiating material remains inside of the transient crater, having been driven downwards by the projectile. Consequently, most of the radiating material is blocked from the side view photodiode (despite its slight elevation), whereas the top view photodiode can see down into the transient crater. As impact angle decreases, the projectile does not penetrate as deeply and its momentum launches some heated ejecta downrange, out of the cavity [5]; thus, additional radiating material is exposed to the side view photodiode and the intensity difference between the oblique side and top views are less than that for the vertical impact. The intensity differences between views indicate that the bulk of the signal source is blocked by the transient crater walls and/or by the optically thick ejecta curtain, remaining unseen when viewed from the side.

The current findings only apply to the dominant thermal signal and not to light emitted from vapor or condensates produced during an impact. The experimental conditions here are designed to minimize vaporization, but the amount of melt and vapor produced can be scaled by the energy of the impactor [6]. The total volume of melt produced will remain greater than the volume of vaporization products for similar nonvolatile materials, even at higher velocities more conducive to producing vapor; the thermal signal should still dominate the overall impact flash.

Implications: Many lunar flashes have been observed since 1999 [e.g., 7-10]. Earth-based telescopes have a fixed viewing position with respect to the Moon, but the location of the impact effectively changes the view orientation due to the curvature of the lunar surface. The results of this study show significant differences in the observed flash intensity when viewed from above versus from the side.

An impact near the edge of the lunar disk will appear to have far less luminous energy than an identical impact near the sub-Earth point. When assuming a luminous efficiency in order to calculate an impactor mass [e.g., 7], a low luminous energy value underestimates the impactor mass by the same factor as the difference between the observed and "actual" luminous energies.

Flash duration is also affected by view orientation. Depending on the sensitivity of the observing instrument, an impact viewed from above will often appear to last longer than an identical impact observed from the side (if the sensitivity is too low, one might only record the early-time spike).

Conclusions: The flash intensity seen from the side is always significantly fainter than the intensity seen from above, and there is a non-negligible impact angle effect. A photodiode in a top view orientation is able to observe radiating material lining the transient crater walls and floor that lie below the pre-impact surface plane, as well as radiating material escaping the crater. For a photodiode in a side view orientation, most of the radiating material (especially in the 90° case) remains hidden by the crater walls and the emerging optically thick ejecta curtain. Consequently, view orientation plays a large part in the observed flash magnitude and duration.

References: [1] Ernst, C. M. and P. H. Schultz (2002) LPS XXXIII, #1782. [2] Ernst, C. M. and P. H. Schultz (2003) LPS XXXIV, #2020. [3] Ernst, C. M. and P. H. Schultz (2005) LPS XXXVI, #1475. [4] Ernst, C. M. and P. H. Schultz (2007) LPS XXXVIII, #2353. [5] Schultz, P. H. et al. (2005) SSR 117, 207-239. [6] Pierazzo, E. et al. (1997) Icarus 127, 408-423. [7] Bellot Rubio, L. R. et al. (2000) Earth, Moon, Planet. 82-83, 575-598. [8] Ortiz, J. L. et al. (2002) ApJ 576, 567-573. [9] Yanagisawa, M. and N. Kisaichi (2002) Icarus 159, 31-38. [10] Cooke, W. J. et al. (2007) LPS XXXVIII, #1986.

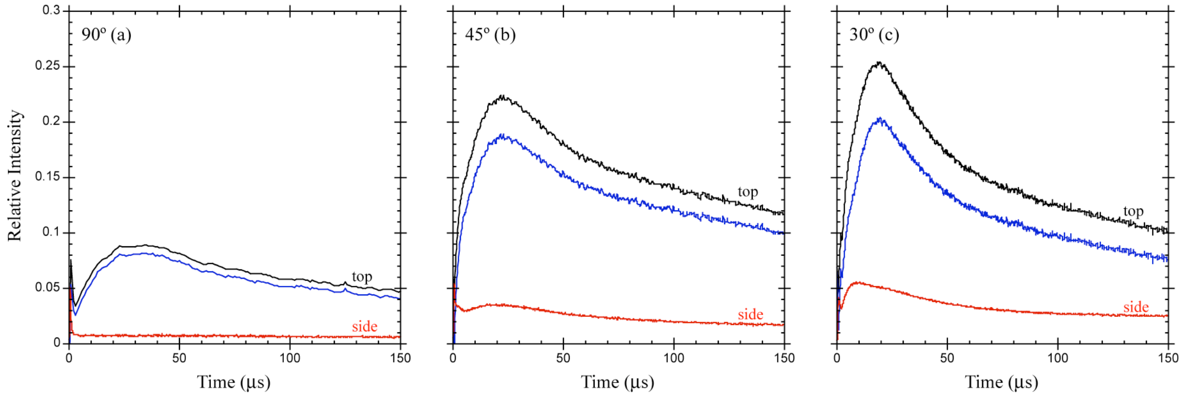

Figure 2. Comparison of top and side view intensity curves for impact angles of 90° (a), 45° (b), and 30° (c). In all cases, the highest (black) curve is the top view data, the lowest (red) curve is the side view data, and the intermediate (blue) curve is the difference between the two.