EXPERIMENTAL INVESTIGATION OF LIGHT FLASH FROM HYPERVELOCITY IMPACTS.

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Introduction: One effect of meteoroid impact on planetary surfaces, for impacting bodies of sufficient mass and speed, is a brief flash of light in the visible or infrared range. In addition to the basics physics questions relating to the impact process, observation of light flash provides a remote diagnostic for impact events and subsequent surface modification. For example, in the case of the Moon, impact-generated light has been observed associated with both Leonid [1] and Perseid [2] meteoroids. In the case of the 1999 Leonid event, Ortiz et al. [3] used previously-established luminous efficiency data to derive an estimate for the flux of impactors.

Laboratory Investigation: Less understood is the relationship between the characteristics of the flash (spectrum, duration, intensity) and the properties of the impactor. Laboratory investigation of the effect is difficult owing to the extreme speeds required (many km/sec); consequently, experimental study of light flash is generally performed on dust grains (micron to millimeter size) accelerated to hypervelocities. Two experimental mechanisms to accelerate dust grains are the light gas gun, which uses gunpowder-driven compression of a light gas such as hydrogen to accelerate larger particles (up to about a millimeter); and electrostatic acceleration, in which a high potential difference of several megavolts is used to accelerate smaller, electrically charged dust grains (up to a few microns in size).

Following pioneering work by Friichtenicht in the mid-1960s, extensive work was done by Eichhorn [4] using the electrostatic accelerator at the Max Planck Institute in Heidelberg, Germany. These studies used photomultiplier tubes to explore the scaling of the light flash effect in both intensity and rise time, as a function of mass, velocity and target material. Strong scaling ($I/m \sim v^A$, A=4 to 5) of the flash intensity was found with respect to the particle velocity.

CCLDAS Facilities: The new electrostatic dust accelerator at the Colorado Center for Lunar Dust and Atmospheric Studies (CCLDAS) at the University of Colorado Boulder permits investigation of the light flash effect using particles of known mass and velocity. The CCLDAS accelerator uses a 3MV potential difference to accelerate charged dust grains into a vacuum beamline. Once in flight, the velocity and mass of the particles are characterized by electrostatic detectors. Active particle selection allows the investigator to specify the desired velocity range for the experiment; particles not meeting the requirements are ejected from the beam before impacting the target. In addition to physics experiments such as light flash investigation, the facility is used for calibration of spaceborne instruments designed to look for dust grains, including the Lunar Dust EXperiment (LDEX) [5] scheduled to fly to the Moon in 2013 onboard LADEE.

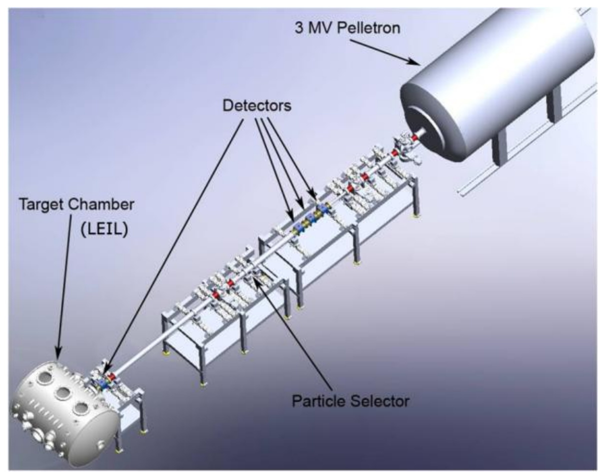

Figure 1: Dust accelerator at CCLDAS

Initial Experiments: Proof-of-concept experiments took place at CCLDAS in the fall of 2011. Micron-sized iron particles accelerated to 1-8 km/sec were impacted on a quartz disc at the end of the beamline. A photomultiplier tube placed directly behind the disc collected impact-generated light transmitted through the quartz. The resulting photocurrent records the flash intensity (over the wavelength range visible to the tube) versus time.

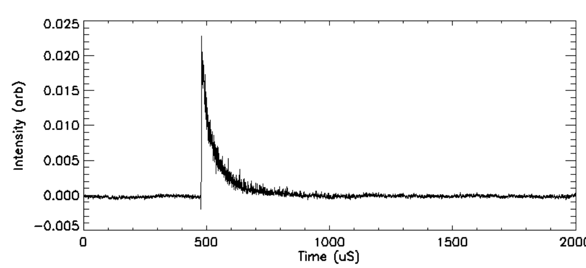

Figure 2: Light flash from an iron particle at 8.3 km/sec

Although the sample size and velocity range was not large enough to permit investigation of scaling, these experiments demonstrated that light flash could be experimentally measured at the CCLDAS facility.

Planned Experimental Program: Measurements by Eichhorn suggest that radiation from the impact-generated cloud fits well to a blackbody curve. Although atomic and molecular lines are known to be present as well [6], measurements of the blackbody temperature on per-particle basis will permit detailed matching between the conditions in the cloud and the (known) properties of the impacting particle. It will also allow investigation of variability in the impact-generated light between impactors of similar character, a topic which has not been carefully investigated but is of substantial interest for the use of light flash as an impact diagnostic.

To perform measurements on a per-particle basis, it is necessary to observe each flash in multiple wavelengths simultaneously. As a first step, we use a series of four photomultiplier tubes coupled to narrowband interference filters. The photocurrent versus time is digitized for each and fitted to a blackbody curve.

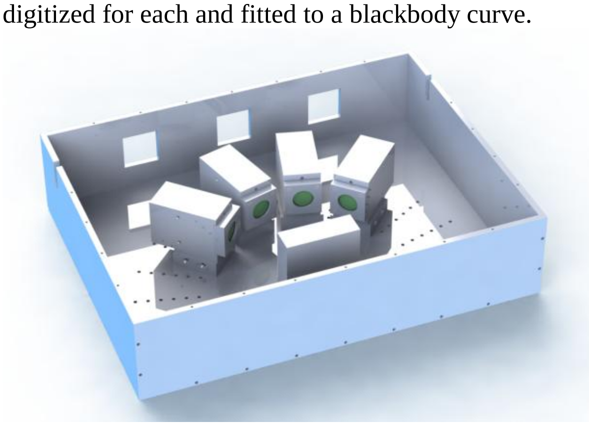

Figure 3: Schematic of light-flash experimental setup, with four photomultiplier tubes. Target is the slab at lower right; dust particles enter through the center square window.

Later experiments are planned to investigate line emission from the impact-generated cloud, and eventually time-resolved spectroscopy over the entire life of the flash.

Complementary Experiments at JSC: The CCLDAS electrostatic accelerator admits observation of particles with very high speeds (up to 50 km/sec demonstrated). However, the technique is limited to smaller particles, a few microns in size (about 10^{-13} kg). The light gas gun at NASA Johnson Space Center provides access to a region of parameter space inaccessible to the CCLDAS facility. Although speeds on the light gas gun are restricted to about 7 km/sec, particles many tens or hundreds of microns in size may be accelerated. A coordinated program of experiments using both facilities will allow exploration of light flash scaling across many decades in velocity and mass.

References: [1] Ortiz, J.L. et al. (2000) *Nature, 405,* 921-923 [2] Yanagisawa et al. (2006) *Icarus, 182 (2),* 489-495. [3] Ortiz, J.L. et al. (2002) *The Astrophysical Journal, 576 (1),* 567-573 [4] Eichhorn, G. (1975) *Planet. Space. Sci., 23,* 1519-1525 [5] Horanyi et al. (2009) *Proc. Lunar Sci. Conf.,* 40th, 1741 [6] Sugita, S. et al. (2003) *J. Geophys. Res.,* 108 (E12), 5140.