Measurement of light flash from hypervelocity dust impacts at the CCLDAS dust accelerator

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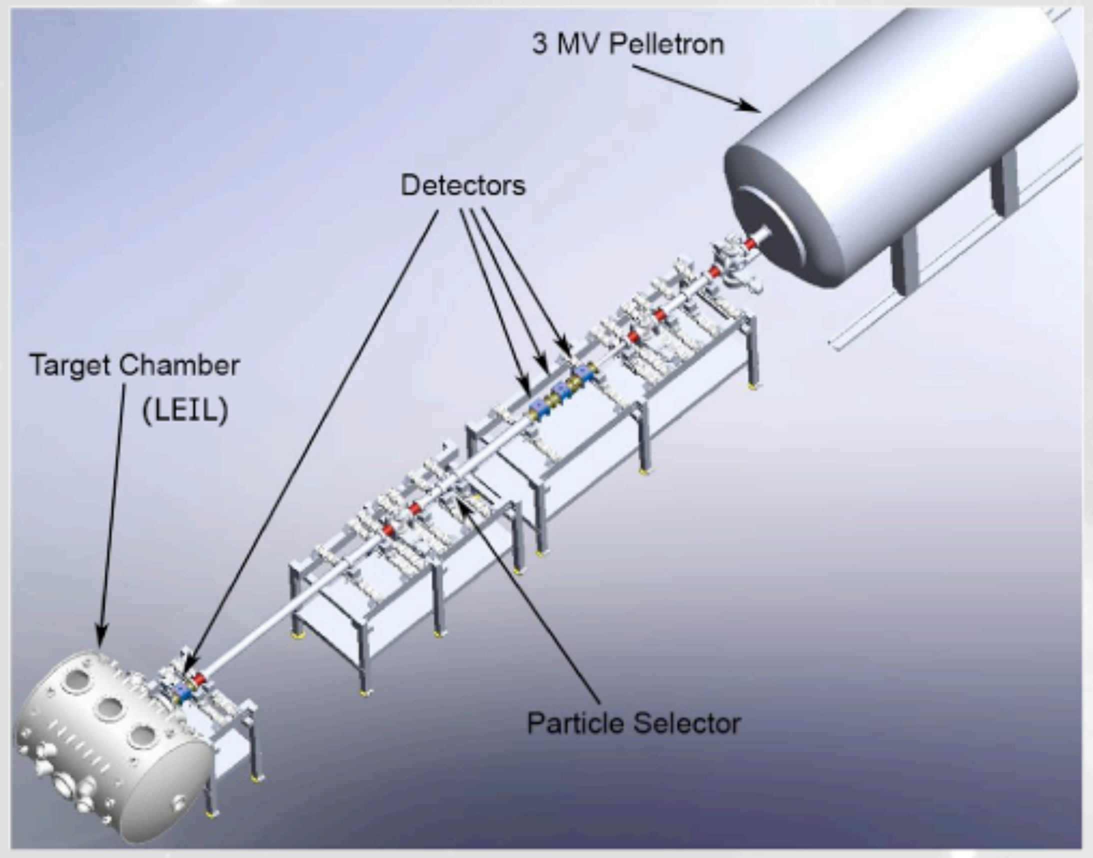
Summary

We report initial measurements of light flash generated by hypervelocity impact of micron-sized dust from the accelerator at the Colorado Center for Lunar Dust and Atmospheric Studies (CCLDAS). The mechanics of hypervelocity impacts, including heating, generation of plasma and neutral gas, particulate ejecta and free-streaming charged particles, are complex and poorly understood despite nearly four decades of research. One well-known effect of such impacts is a burst of light which spans the first tens to hundreds of microseconds following the impact event. Time-resolved analysis of emitted light, including spectral information, is a valuable diagnostic tool providing information about the evolution of the impact-generated plasma.

As part of a planned comprehensive study into the characteristics of the impact-generated plasma, we will perform complimentary experiments on impact-generated light flash at the CCLDAS dust accelerator and at the Light Gas Gun facility at NASA Johnson Space Center. The CCLDAS dust accelerator is designed to launch micron- and submicron-sized particles at speeds of 1km/sec to 100km/sec; the Light Gas Gun is capable of accelerating particles up to a millimeter in size at speeds of 3.5-7 km/sec. A program of experiments spanning the two facilities provides the opportunity to explore scaling of plasma characteristics over many decades in velocity and mass. We present initial results from photomultiplier tube (PMT) observation of light flashes at the CCLDAS accelerator, along with an overview of the current theoretical understanding of their origin.

CCLDAS Dust Accelerator



The newly-comissioned dust accelerator facility at CCLDAS uses a 3MV potential difference to launch micron-sized and smaller dust grains. Dust particles are given a small positive charge at one end of a vacuum beamline, which is held at 3MV relative to lab ground. They are accelerated by this potential difference and traverse a number of image-charge detectors which determine charge and velocity, from which mass can be derived.

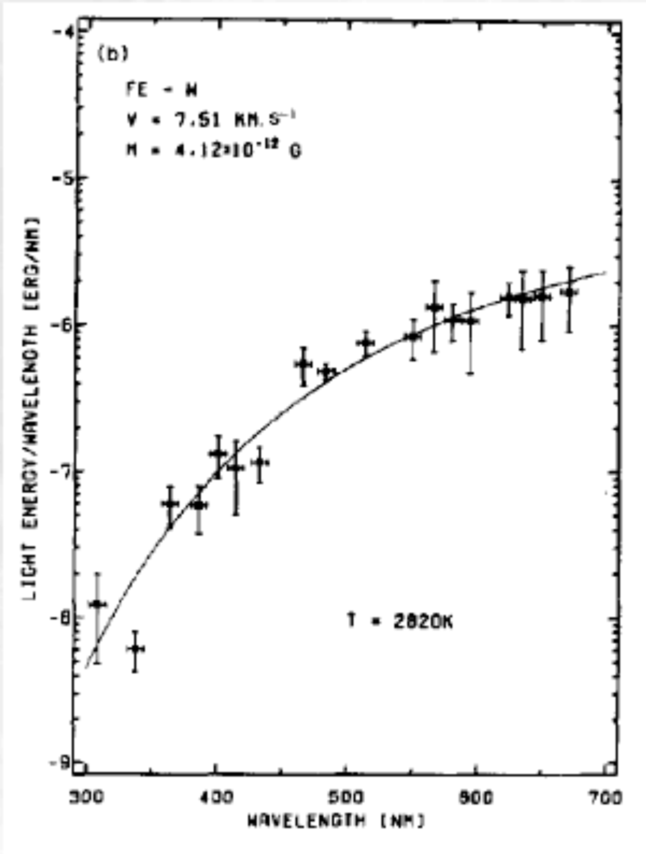
An automatic particle-selection unit permits real-time rejection of particles which do not meet predefined velocity or mass criteria. This system allows an experimenter to program in narrow velocity and/or mass ranges, for example, to investigate scaling phenomena.

- Velocity range: 1km/sec to 100km/sec design speed (1-10km/sec presently)
- Particle sizes: Up to 1 micron

Light Flash

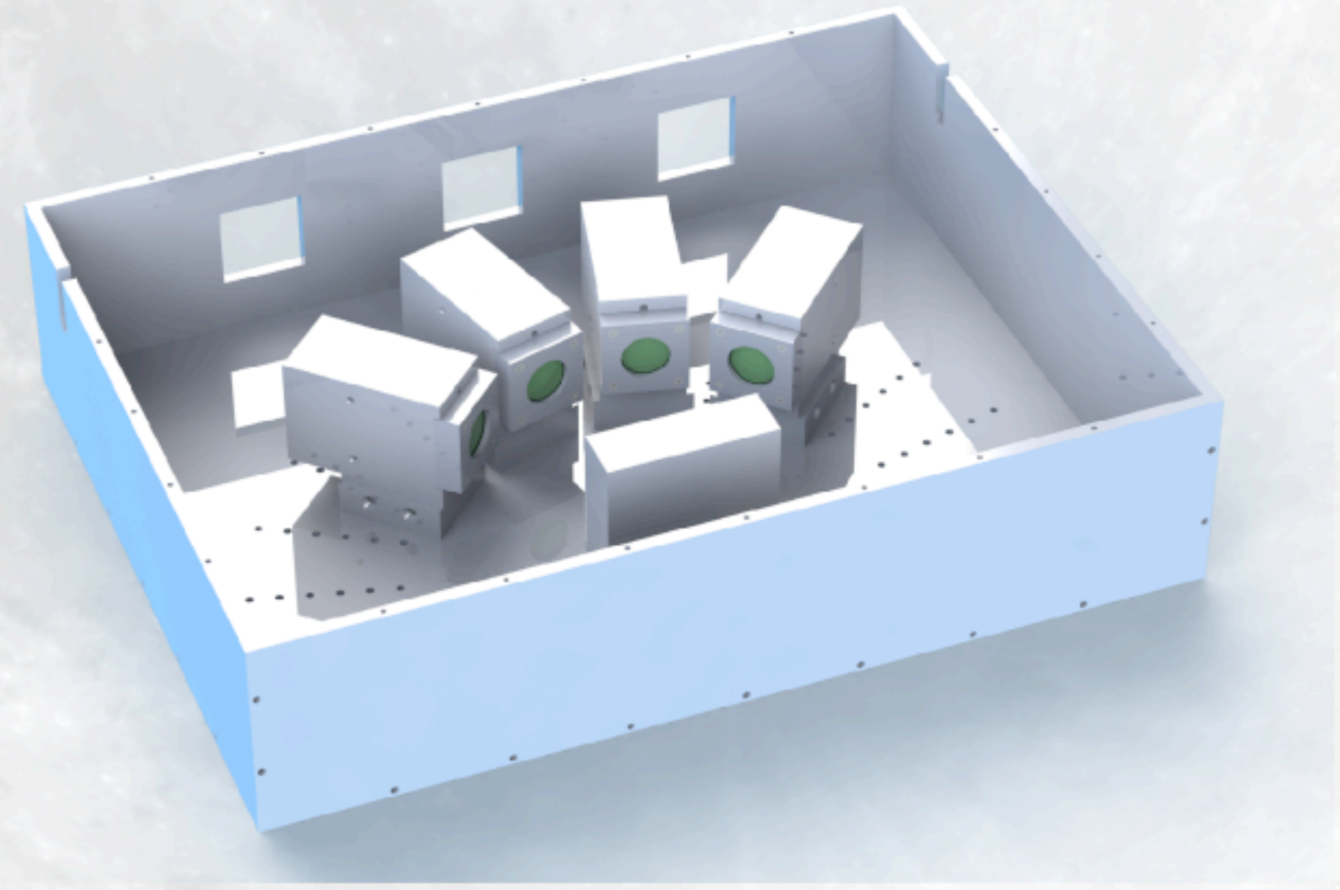
Hypervelocity particle impacts onto solid surfaces produce a complex range of phenomena. Because of the small length (10's of microns) and time (<100uS) scales involved in a typical dust-impact experiment, radiated light is one of the few diagnostics which permits measurement of the impact process as it occurs.

The example plot at right (Eichhorn, 1978) shows wavelength-resolved measurements carried out by observing impacts with photo-multiplier tubes coupled to narrowband filters. The data points are derived from multiple separate experiments conducted at fixed velocity and and mass settings. The time- and ensemble-averaged spectrum fits well to a blackbody curve.



Later experiments (e.g. Sugita et al. 2003) measured emission lines in the impact-generated light and investigated scaling with impact parameters. The full spectral behavior of the impact flash as a function of time remains unclear.

Time-Resolved Multi-Wavelength Measurements



A set of four photomultiplier tubes observe the target directly. Each is fitted with a separate narrowband interference filter. Assuming the impact-generated gas cloud radiates as a blackbody for some portion of its lifetime, the four wavelength samples permit measurement of the time evolution of the temperature. This is in contrast with previous experiments (e.g. Eichhorn 1976) which establish an average temperature.

Emission lines are also known to be present; filters tuned to those wavelengths will permit investigation of their time evolution and to what extent they dominate the blackbody radiation during the evolution of the cloud.

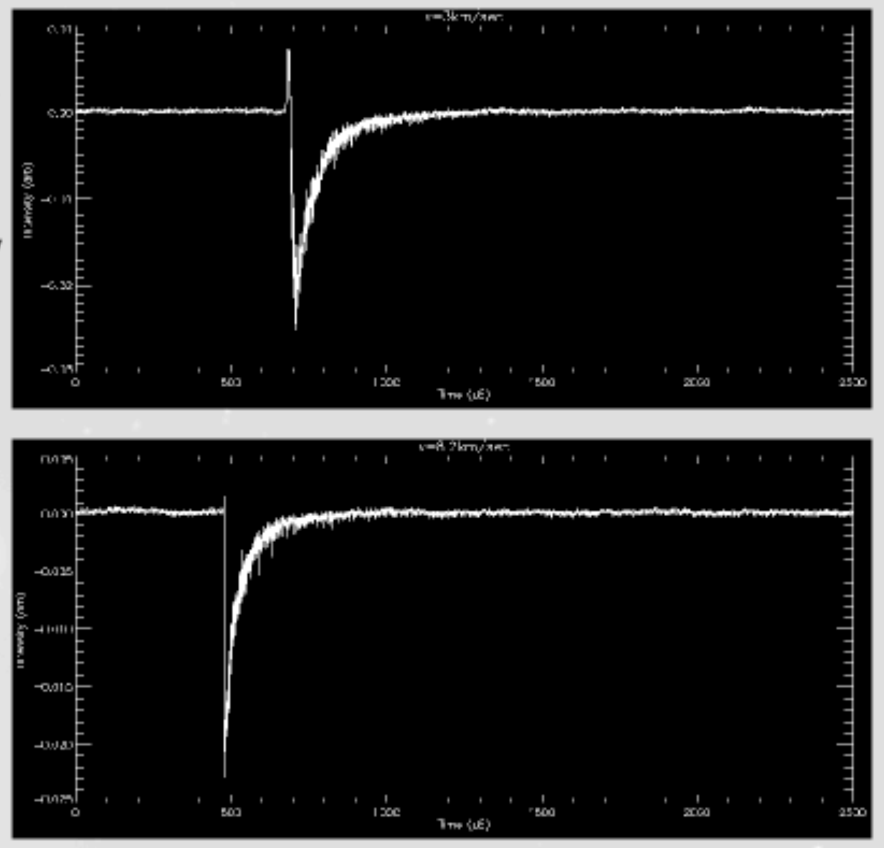
CCLDAS Observations

Initial experiments were carried out by terminating the dust beam at a quartz disc mounted on a vacuum window. This allowed a PMT to be mounted extremely close to the impact point, observing nearly 2π solid angle.

Experiment was a proof-of-concept demonstrating the feasiblity of light flash observations at CCLDAS. The following areas of improvement were identified:

(1) The particle rate is insufficient at speeds above 2-3 km/sec. Light generation is a strong function of the velocity and there are too few fast particles to explore scaling.

(2) Tubes require an integration time on the order of a microsecond. Operation in "fast" mode produces a signal that must be smoothed digitally.



(Top) Flash from a 3 km/sec particle
(Bottom) Flash from an 8.2 km/sec particle

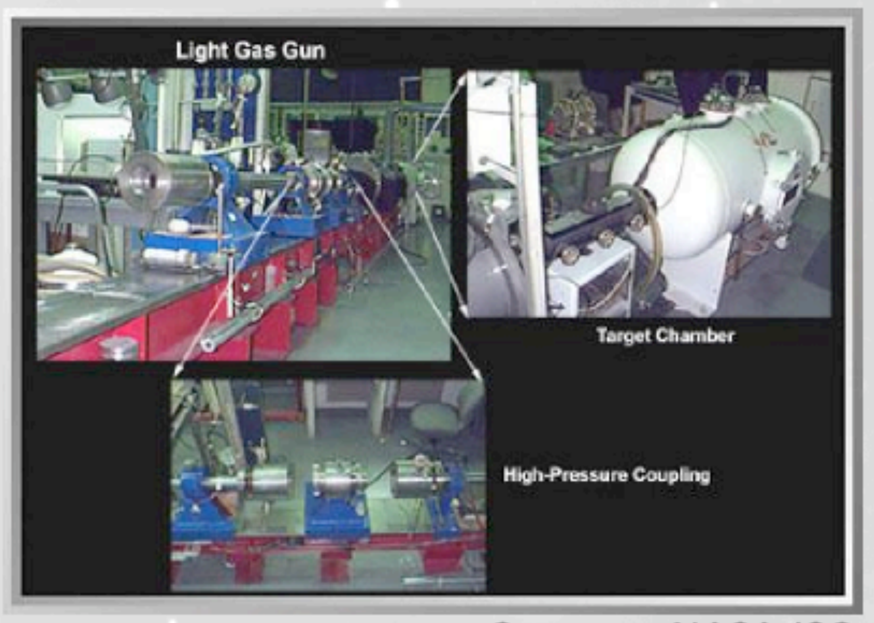
Both signals are digitally smoothed with a 1uS time constant.

See also P43A-1664 (Thursday) by K. Drake

JSC Light Gas Gun

The CCLDAS facility, while offering high speeds, is limited to smaller particles. A complementary facility exists at JSC. The Light Gas Gun permits acceleration of particles up to a millimeter in diameter at speeds of up to 7 km/sec.

A program of experiments spanning both facilities offers the chance to explore scaling of light-flash behavior over many decades in mass and velocity.



Courtesy NASA JSC

References

- G. Eichhorn, Analysis of the Hypervelocity Impact Process From Impact Flash Measurements, Planet. Space Sci, 24, 771.
- G. Eichhorn, Heating and Vaporization During Hypervelocity Particle Impacts, Planet. Space Sci 26, 463.
- S. Sugita et al., Intensities of Atomic Lines and Molecular Bands Observed in Impact-Induced Luminesence, J. Geophys. Res, 108 (E12) 5140.