EXPERIMENTAL MEASUREMENT OF THE SUB-MICRON EJECTA FROM HYPERVELOCITY IMPACTS INTO METEORITES. H. B. Throop[1,2], D. D. Durda[3], A. Shu[4], R. H. Geiss[5], D. James[4,6], B. Tompkins[5], K. P. Rice[7]. [1]Planetary Science Institute (1700 E Ft Lowell Blvd, Tucson, AZ 85719; throop@psi.edu), [2]Physics Department, University of Pretoria (South Africa), [3]Southwest Research Institute (1050 Walnut St Ste 300, Boulder, CO 80302), [4]University of Colorado (3400 Marine St, Boulder, CO 80309), [5]Central Imaging Facility, Department of Chemistry, Colorado State University (Ft Collins, CO 80523), [6]Laboratory for Atmospheric and Space Physics (1234 Innovation Drive, Boulder, CO 80303), [7]Current address: Cameca Instruments (5500 Nobel Dr., Madison, WI 53711).

Abstract: We present the first results from thousands of hypervelocity (10–40 km/sec) impacts of micron-sized dust grains into a meteoritic target. We find that the size distribution of the ejecta follows a rough power law down to ~0.05 μm. The slope of the distribution is slightly shallower at these sizes than has been measured before at larger sizes, suggesting a change in the physics of fracturing around 1 μm. Our work is the first direct measurement of ejecta in this size range, which is the dominant source for dusty rings and the zodiacal cloud.

Overview: Our goal is to study the physics of hypervelocity impacts by small dust grains into solid targets. These impacts are important in the production of dusty planetary rings and meteoritic (zodiacal) dust [1,2]. For rings, the majority of visible dust in rings such as Saturn's G and D rings is believed to be from micron-sized impacts, yet virtually no experimental studies have been performed at these size scales. There are no experimental constraints on either the dust ejecta yield or the size distribution of the ejecta.

Hypervelocity dust source: We are using the dust accelerator at the Institute for Modeling Plasmas, Atmospheres, and Cosmic DusT (IMPACT)[1] which provides a continual stream of hypervelocity grains which can be studied in impact experiments. The beam can produce tens of thousands of impacts/day, compared to 1-3 impacts/day (of larger projectiles) at gas-gun facilities such as the Ames Vertical Gun Range (AVGR) which have been used for most previous impact experiments [3,4].

The IMPACT accelerator [5] works by charging individual Fe grains and passing them through a 3 MV potential. Masses range from 10^{-18}–10^{-10} g (diameters 0.05–3 μm), and velocities are 1–50 km/sec. The beam control system measures a particle's velocity and mass as it is accelerated, and a particle selector optionally allows individual grains to be removed from the beam. Particles impact the experiment in a vacuum chamber at the end of the 15 meter beamline. Before particle down-selection, the beam produces particles at a rate of ~ several grains/sec, spread over a beam diameter of ~ 1 cm.

Foil dust detectors: We measure the ejecta from each impact by using ultra-thin gold foils suspended so as to intercept the ejecta. The foils are created with vapor deposition to make Au films of thickness 0.1 μm atop a 0.003-μm carbon substrate. The foils are supported by a 3 mm diameter 400-mesh copper grid (London #LF400). Our vapor-deposited foils are thinner, stronger, and more uniform than rolled Au foils. While the foils are our main targets, the Cu structure of the grids themselves provides a thick secondary target useful for calibration and comparison with previous results. Typically the particles punch clear holes through the thin Au foils, and create impact craters and/or embed themselves in the thick Cu.

In Phase I of our experiment [6], we reported on the relationship between particle diameter and hole size for a variety of dust velocities and foil thicknesses (1-15 km/sec, 0.05 – 0.5 μm). For thin foils, we found the hole diameter to be comparable to the impactor size or slightly larger, in line with previous results [7]. In Phase II, discussed here, we report on the results of using the foils to directly detect impact ejecta.

Experiment: We directed the beam such that the particles would impact a polished 1 cm^2 sample of meteorite NWA 869, causing material to eject from its surface with each hit. This sample was chosen because it contains comparable fractions of Si-rich and Ni-rich regions and is broadly representative of the source material for the zodiacal cloud and Jupiter's rings. We then placed six ultra-thin gold foils 1.5 cm from the impact site at a variety of positions in order to capture the ejecta. We exposed the target for 24 hours, which yielded ~9800 impacts at 10-40 km/sec. We then removed the foils and used a scanning electron microscope (SEM) to measure the holes created by ejecta.

Results: We measured 161 holes in our Au foil, ranging in diameter from 0.1 μm – 4 μm. The size distribution is shown in Figure 1. Smaller holes likely were made but were below our chosen SEM resolution. Asymmetry in many of the holes indicates that the ejecta velocities are lower than the beam impact speeds.

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Assuming a 1:1 relationship between hole size and particle size, we find that the ejecta follows a rough power law, with the number of particles increasing with decreasing size. Ejecta at larger sizes also follows a power law [3]. The slope of the power law appears to decrease in the regime we study; i.e., there is an underproduction of small grains. This might be due to the difficulty of breaking fracturing micron-sized crystalline structures or other changes in physics at small sizes. Such a production function is opposite that required for some models of Jupiter's dusty ring, which require a steepening of the distribution at sub-micron sizes [8].

Our results here are preliminary and include only one of the six exposed foils. Results from the remaining samples will be presented at the meeting.

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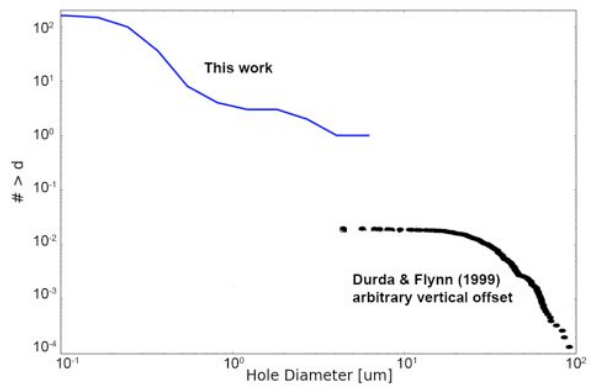

Figure 1. Size distribution of hypervelocity meteoritic ejecta. Our new results (top curve) extend the existing measurements by 1-2 orders of magnitude. The production curve appears to become shallower at the small sizes we measure here.

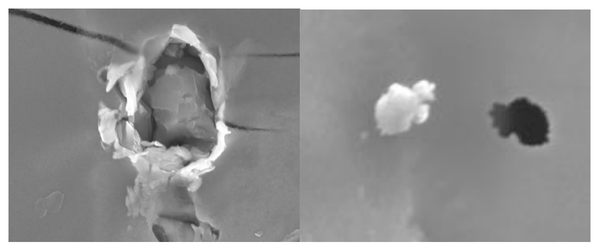

Figure 2. Left: micron-sized ejecta grain embedded in Cu surface, surrounded by raised rim. Right: micron-sized ejecta grain has punched a hole through Au foil, leaving particle and/or foil 'cap' nearby.

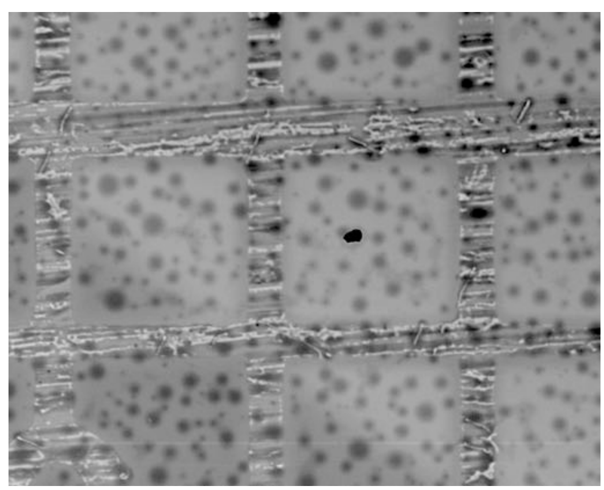

Figure 3. Wide-angle view of Cu grid (lines) and suspended Au foil (squares). A single large ejecta hole is punched in the middle. The asymmetrical hole shape is likely due to the low ejecta speed. Image width 200 μm.