Experimental Investigation Of Fine-Grained Rim Dust Aggregation Graeson Griffin, Jorge Martinez, Lorin S. Matthews, Truell W. Hyde, *Center for Astrophysics, Space Physics and Engineering Research (CASPER)*, Baylor University, One Bear Place #97283, Waco, Texas 76798-7283 Graeson_Griffin2@baylor.edu

Introduction: Chondrites compose 80% of all meteorites found on earth, and chondrules make up 60% to 80% of their composition. [8] It is theorized that chondrules may provide a record of the environment surrounding them during their formation, allowing an indirect mechanism for measuring the powerful dynamics present in the protoplanetary disk environment [4] [5]. Covering the crystalized chondrule is a rim of fine dust. This rim differs from the surrounding matrix in both its composition and porosity, suggesting that it did not form inside the more extensive body but rather around the chondrule before it aggregated into the larger body [1] [6]. Therefore, understanding how such rims form offers critical information to our understanding of the protoplanetary disk environment.

This project combines theoretical, observational, computational, and experimental work to examine this question. A technique for extracting 3D models of chondrules from chondrites has been developed by R. Hannah [1], where only the portion of a chondrule exposed from a slice had been observed previously. This has confirmed data connecting the chondrule rim size to the radius of the chondrule itself as well as provided additional data concerning porosity, roughness, and shape. The presence of a non-zero constant in the linear fit (shown in figure 1) is particularly interesting. The resulting constant provided by the correlation between the chondrule radius and the thickness of its rim is the focal point of Liffman's 2015 paper [2], in which he proposes a multi-velocity approach to the formation of chondrule rims.

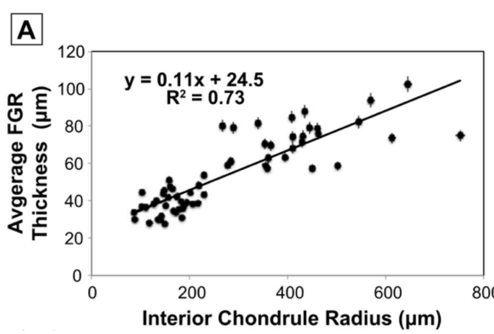

Figure 1: Data from R. Hanna's 2015 paper displaying the equation for the correlation line and the correlation coefficient R. [1]

Additional research along this line has recently been provided by C. Xiang [3]. Her numerical simulation maps dust particles of various sizes and speeds interacting with a chondrule surface. The resulting 'rubble pile' is shown in figure 2. The left image provides a 3D representation of the pile with the right image showing a vertical 2D slice of this 3D structure. In the 2D slice, the porosity of the pile is evident.

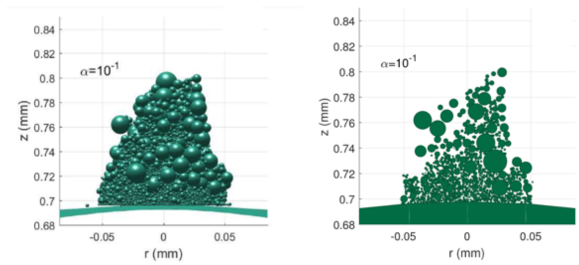

Figure 2: Simulation results from C. Xiang et al. The left image is a 3D representation of the 'rubble pile' comprising the FGR, with the right image a vertical 2D slice of this 3D structure. [3]

Experiment: The experiment discussed below was carried out in a GEC reference cell with no plasma ignited for the duration of the investigation and a cryopump holding the tank at a pressure of 2E-5 Torr. The two dust types used were 20-micron spherical alumina dust and JSC-1 lunar simulant. All images were captured using two GreyPoint cameras with 100mm lens' positioned orthogonally above and to the side of the target position. The upper lens was focused on a polished Delrin stand placed on the lower electrode with the side lens focal point depending on the point of observation within the rubble pile. Both dust types were used in each scenario.

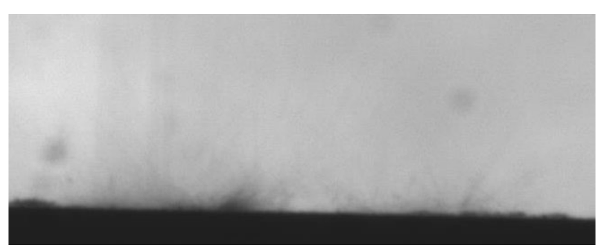

Figure 4: Splashing captured during a 20-micron alumina dust drop.

In each experiment, two dust droppers were employed. The first dropped the dust directly onto the target surface but also blocked the top camera. The second dust dropper dropped the dust onto the surface but at an angle. Although this eliminated the top camera obstruction it provided a significant horizontal velocity to the dust. All particles were illuminated using a backlight during drops to allow for observation of dust interaction. As shown below, some 'splashing' can be observed in Figure 4 as dust impacts the surface. The dusty surface was scanned employing two coherent stingray lasers in order to determine final positions.

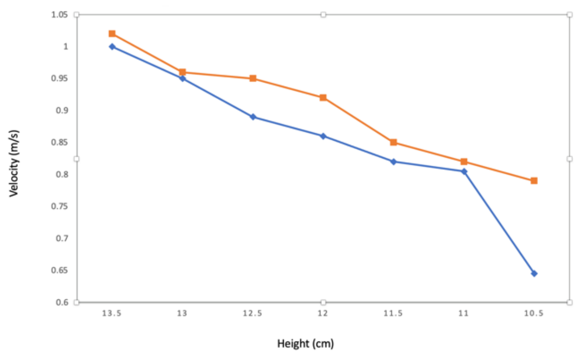

Figure 3: Average dust velocity from the angled dropper. (Orange: total velocity. Blue: velocity in the y direction.)

3D Representation: The ultimate goal of these experiments were to track the dust pile evolution over time. However to track these changes, a topographical map of the surface is needed. This information was obtained by scanning both horizontal and vertical laser sheets across the dust pile. Videos of these scans were then analyzed, and the information used to create a 3D topological map of the surface (shown in Figure 5). This 3D map consists of many 2D slices of the piles stacked on top of each other. The information for generating these maps was captured by taking a video of the laser sheets as they scanned through the dust piles. The result is a video in which the slopes of the piles are illuminated segmentally over each successive frame. The result is a time-lapse of the surface evolution as more and more dust is dropped onto the surface. One of these frames is displayed in figure 5.

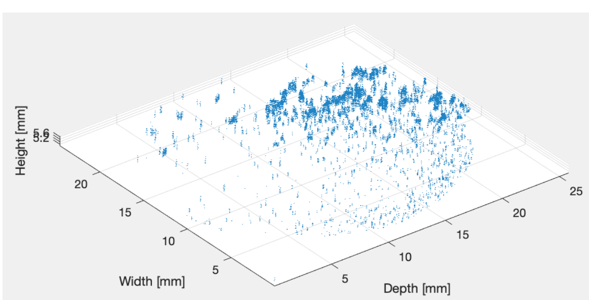

Figure 5: 3D virtual representation of a surface retrieved from laser scans of a rubble pile in the lab.

Here one can see the scale of the experiment. Clumping occurred more toward the top of the surface due to the placement of the dust dropper above the surface.

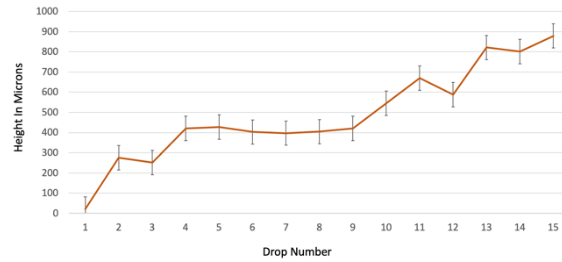

Figure 5: Max rubble pile height (microns) over 15 drops using 20 micron dust.

In conclusion, the ability to resolve dust on a surface in such a way as to track agglomeration on that surface has been demonstrated. This data allows for the investigation of dust clumping and the heights obtained by piles under different parameters including impact speed of the dust, particle, size, and charge. For future work, the number of rubble piles that form over the course of many drops will be examined and counted. Height and "pile density" of experimental rubble piles can then be compared with simulated results. Utilizing the tools created for this work, dust impacts between 2 and 10 m/s and the evolution of a surface affected by these impacts can be examined. In future experiments the dust material and target material will also be varied.

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References: [1] Hanna, R. D., & Ketcham, R. A. (2018). *Earth and Planetary Science Letters*, 481, 201–211. [2] Liffman, K. (2019). *Geochimica et Cosmochimica* Acta, 264, 118–129. [3] Xiang, C., Carballido, A., et al. (2019). *Icarus*, 321, 99–111. [4] Carballido, A. (2011). *Icarus*, 211(1), 876–884. [5] Ormel, C. W., Cuzzi, et al. (2008). *The Astrophysical Journal*, 679(2), 1588–1610. [6] Beitz, E., Güttler, C., et al. (2013). *Icarus*, 225(1), 558–569. [7] Binzel, Richard P., et al. Meteorites and the Early Solar System II. Edited by D. S. Lauretta and H. Y. McSween, University of Arizona Press, 2006. [8] Weisberg, Michael K., et al. "Systematics and Evaluation of Meteorite Classification." Meteorites and the Early Solar System II, edited by D. S. Lauretta and H. Y. McSween, University of Arizona Press, 2006, pp. 19–52,