**SIZE AND SHAPE DISTRIBUTIONS OF CHONDRULES AND METAL GRAINS REVEALED BY X-RAY COMPUTED TOMOGRAPHY DATA.** J. W. Nettles and H.Y. McSween, Jr. Department of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN, 37996 (jnettle1@utk.edu)

**Introduction:** The variation in chondrule sizes and shapes are commonly attributed to a sorting mechanism that existed in the solar nebula. This sorting mechanism has also been called upon to possibly explain the metal-silicate fractionation that occurred in the nebula. However, because of complexities surrounding the measurement of chondrule sizes and shapes, the exact nature of the chondrule sorting mechanism remains unproven. Sorting by mass and sorting by aerodynamic properties have both been proposed in the literature [1,2]. The testing of sorting mechanisms is fairly simple in concept because whatever mechanism sorted chondrules should also have acted on other nebular particles such as metal grains. Therefore, if the mass distribution of chondrules in a meteorite is similar to the mass distribution of metal grains, and if this is true for many meteorites, this is evidence that nebular particles were sorted by mass. Accordingly, similar distributions of chondrule and metal grain aerodynamic properties (a function of both shape and mass) are evidence for aerodynamic sorting of these particles.

Testing of these hypotheses has proven difficult because of the difficulties of actually measuring the size and shape distributions. Measuring sizes by disaggregation is destructive and makes information on the textures, compositions, etc. of the disagreggated chondrules difficult to obtain, and thus has been done in a limited fashion. Instead, sizes and shapes of nebular particles are usually measured from thin sections. Unfortunately, the diameters (for example) of chondrules measured in thin sections are the true diameters only in the rare case that the thin section cuts equatorially through the chondrule. In most cases, the diameter of a chondrule measured in thin section is an “apparent diameter.” This makes comparison of thin section-based data to disaggregation data inappropriate, although statistical corrections (e.g. [3]) have been used to convert the apparent diameters to true diameters in order to make the comparison more appropriate. Metal grains are even more difficult because they have irregular shapes.

An approach to measuring chondrule sizes that makes chondrule and metal grain size and shape measurements easily comparable is to use X-ray computed tomography (CT, commonly called catscan) data. CT data also makes possible the measurement and comparison of shapes of both metal grains and chondrules. [2] first tried to test nebular sorting hypotheses by comparing sizes (which were converted to mass) of chondrules and metal grains. While X-ray CT data were used to measure size distributions of metal grains in that study, chondrule size distributions were made from thin sections. Also, Type 4 meteorites were used previously, and the possible flattening of particles that can accompany thermal metamorphism, which changes the size distributions, made their results preliminary. We have acquired X-ray CT data for three Type 3.x meteorites in order to measure size and shape distributions of meteorites with the least amount of thermal metamorphism possible in an attempt to test nebular sorting hypotheses.

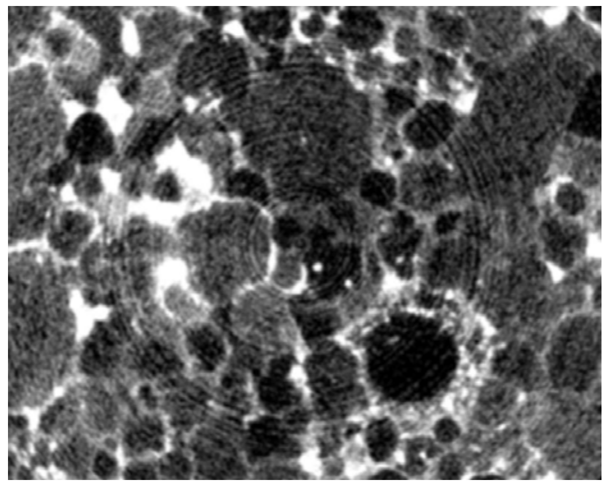

**Figure 1.** Example Krymka slice. FOV is 10mm wide. Chondrules with different grayscale values are evident in the image, corresponding to rough differences in chondrule compositions.

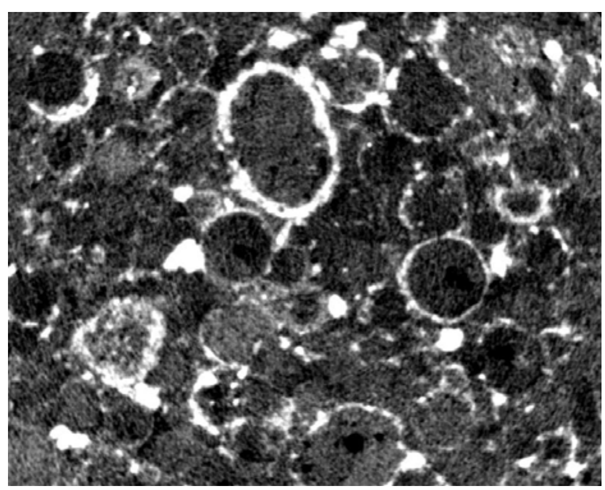

**Figure 2.** Semarkona slice with 12 mm wide FOV.

**Methods:** X-ray CT data for three meteorites were acquired at the University of Texas at Austin's High Resolution X-ray CT Facility. The meteorites scanned are Krymka (LL3.1), Semarkona (LL 3.0), and Sharps

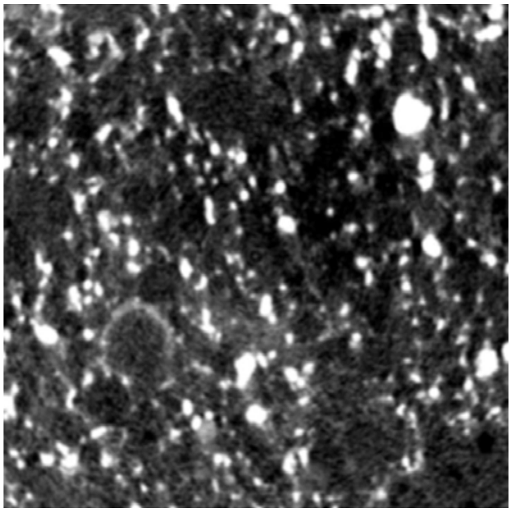

**Figure 3.** Example slice of Sharps. Note that chondrules are much less evident in this meteorite.

(H3.4). Metal grains were identified in the X-ray CT slices by selecting voxels (three-dimensional pixels) above a certain threshold since metal grains are relatively dense and therefore bright in CT data. The density of chondrules does not contrast with the rest of the meteorites as well, so outlines of chondrules were traced (creating "regions of interest") using the IDL software package. Once the two components (chondrules and metal grains) were identified, a software tool called Blob3D developed at the High Resolution X-ray CT facility was used to make the size and shape measurements.

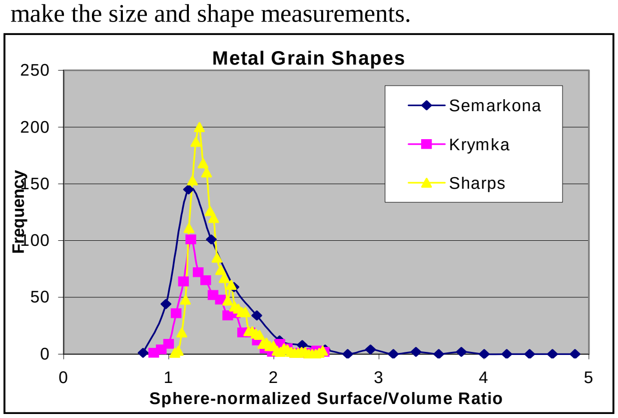


**Figure 4.** Histogram of metal grain volumes.

There were several specific size and shape parameters actually measured using the Blob3D program. Size measurements included maximum diameter and volume, while shape measurements include surface area to volume ratio, a sphere-normalized surface to volume ratio, and minimum and maximum projected surface area. Measured volumes of chondrule and metal components are converted to mass using density. Aerodynamic stopping time, the relevant aerodynamic property, is calculated as $t_s = r_p \rho_s / c \rho_g$, where $t_s$ is the stopping time in seconds, $r_p$ is the radius of the particle with density $\rho_s$, c is the gas sound speed, and $\rho_g$ is the density of the gas [4].

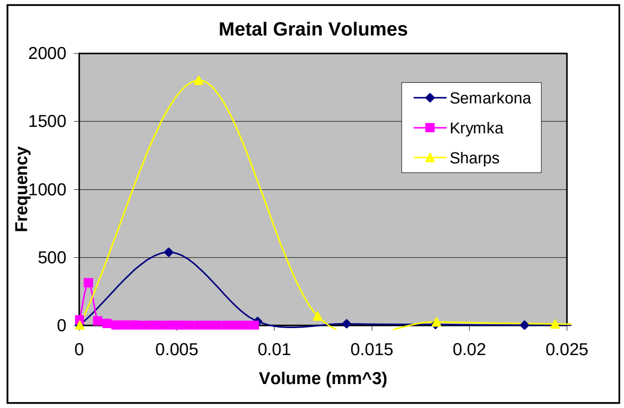


**Figure 5.** Histogram of surface/volume ratios for metal grains, normalized to spheres.

Minimum projected surface area is the smallest two-dimensional shape that can be found from a three-dimensional object and, under the assumption that this surface area would represent the most aerodynamically efficient way for the particle to travel through the nebula, this parameter is used to test for shape-sorting in the nebula. Similar chondrule and metal grain distributions of mass, aerodynamic stopping time, or minimum projected surface area are then evidence for mass, aerodynamic, or shape sorting in the nebula.

**Results and Discussion:** Figures 1, 2, and 3 are example slices of Krymka, Semarkona, and Sharps, respectively. Observations that can be made simply by inspecting example slices are that chondrules in Sharps are smaller and not as well defined as in Semarkona or Krymka. The quantitative chondrule analyses are in progress and will be presented at the conference. Metal grain distributions are complete, however. Figures 4 shows distributions of sphere-normalized surface to volume ratio (SNSVR) for the three meteorites. If the particle was spherical, its SNSVR would be one, so from Figure 4 we see that most metal grains have surface/volume ratios slightly less than that of a sphere. Metal grain volumes are presented in Figure 5. Of note is that Krymka's average metal grain volume is much less than that of the other two meteorites. Comparisons of chondrule and metal grain distributions will be presented at the conference.

**References:** [1] Scott E.R.D and Haack H. (1994) *Meteoritics*, 28, 434. [2] Kuebler K.E. et al. (1999) *Icarus, 141*, 96-106. [3] Eisenhour D.D (1996) *MAPS*, 31, 243-248. [4] Cuzzi J.N. et al. (1996) in *Chondrules and the Protoplanetary Disk* (R.H. Hewins et al., eds.) pp. 35-43, Cambridge Univ.