EVIDENCE FOR A BIMODAL DISTRIBUTION OF COSMIC DUST DENSITIES.
G.J. Flynn[1] and S.R. Sutton[2]. (1) Dept. of Physics, SUNY-Plattsburgh, Plattsburgh, NY 12901, (2) Dept. of Geophys. Sci., Univ. of Chicago, Chicago, IL 60637.

The density of cosmic dust particles is an important parameter in the calculation of orbital evolution timescales (and thus solar flare track density) and peak temperatures reached on atmospheric entry. Both track density (1) and peak temperature (2) have been used to distinguish between asteroidal and cometary sources of stratospheric cosmic dust. Based on density measurements by Fraundorf et al. (3), who found that 7 small (all but one $\leq$ 11 µm) stratospheric cosmic dust particles ranged in density from 0.7 to 2.2 gm/cc, the particles have generally been modeled as having a density of 1 gm/cc (1,2). However SEM observations indicate there are two distinct morphological types of chondritic cosmic dust (4), "porous aggregates" and "smooth particles," suggesting two different density groups. Examination of the depth to diameter ratios of microcraters on the surfaces of glassy lunar spherules by Smith et al. (5) supports the idea that two distinct types of stony micrometeoroids exist, having densities near 2.7 gm/cc and 1.2 gm/cc. If true, particles from the lower density group would experience significantly more rapid orbital evolution and less atmospheric entry heating than particles from the higher density group with similar initial parameters.

We have inferred the densities of 12 stony micrometeorites recovered from the stratosphere in the JSC Cosmic Dust Collection Program. These 12 particles, all "C-type" except U2001B6 which is called "C?" in the JSC preliminary classification, range in size from 6 µm to 35 µm. Particle masses were determined in a three step procedure: the mass of iron in each particle was determined by Synchrotron X-Ray Fluorescence (SXRF), the Fe to Si ratio was determined by measuring peak heights from the JSC catalog spectra, and the Si abundance was assumed to be CI (6). Particle volumes were determined using an optical microscope to measure 3 dimensions and an approximate shape, as described by Sutton and Flynn (7). The volume of one particle, U2022G1, was determined by SEM measurement of 2 dimensions and inference of thickness (6). This particle was unavailable for analysis by the improved optical technique.

The density results for all 12 particles are reported in Table I. W7027C5 is larger than the analysis beam, thus we underestimate its iron content and report only a lower limit on its density. The mean particle density is 1.2 gm/cc, in good agreement with the assumption of a 1 gm/cc density. However, as can be seen in Figure 1, the density distribution is bimodal, with few particles having densities near the mean value. The mean densities for particles in each group are 0.7 $\pm$ 0.2 gm/cc and 1.7 $\pm$ 0.2 gm/cc.

As a blind test of this approach we used the same technique to infer the densities of 12 fragments of standard glass (SRM 1876 K546) in the same size range as the cosmic

Table 1: Particle Densities

Particle	Shape*	Dimensions (x,y,z in µm)	Density (gm/cc)
W7029*A27	S	diameter = 10	1.6
U2015G1	P	17,20,20	1.6
W7027C5	P	22,30,35	> 0.5
U2022G17	E	8,8,14	0.4
W7013H17	P	12,12,15	0.8
W7013A11	P	17,12,26	1.7
U2022G2	R	15,7,15	2.0
U2022B2	P	12,18,15	0.8
U2022C18	R	11,9,14	0.9
U2001B6	C	diam = 25, 15	0.6
W7066*A4	R	7,6,8	1.7
U2022G1	R	30,20,15	0.7

*SHAPE: R = rectangular box: C = cylinder: E = ellipsoid: S = sphere: P = intermediate to R and E [Vol(P) = 0.75 Vol(R)]

BIMODAL DISTRIBUTION OF COSMIC DUST DENSITIES: Flynn G. J. and Sutton S. R.

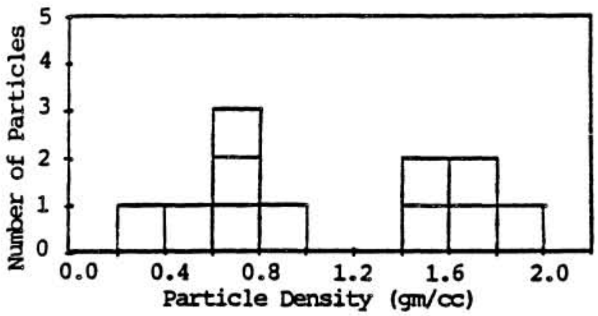
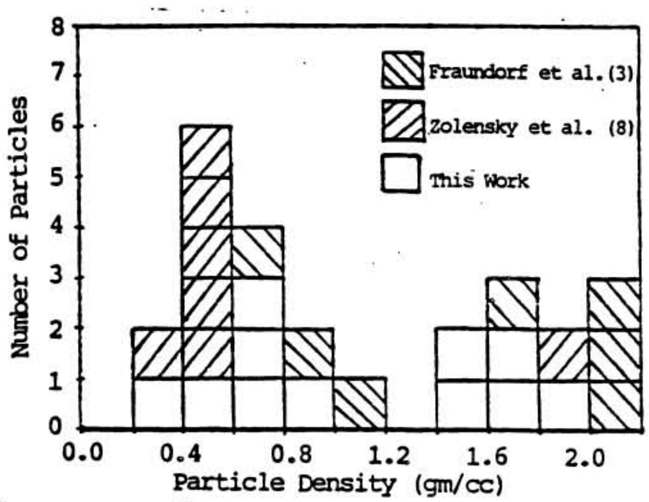


Figure 1 (above). Cosmic dust densities by SXRF show a bimodal distribution.
Figure 2 (right). The bimodal distribution remains with only slight peak shifts when other literature data are added.



dust particles. We obtained a mean density of 2.0 gm/cc, which is within 10% of the true density of 2.2 gm/cc. The individual density determinations spread around the true value with a σ = 40%. Since the glass tended to break into very thin, irregular fragments, the volumes were much more difficult to measure than for the cosmic dust particles. Thus our individual cosmic dust particle densities are likely to be valid to better than the $\pm$ 40% seen for the glass fragments. This notion is supported by the small standard deviations of the two cosmic dust density peaks, 30% and 12% for the low and high density, respectively. The densities of the standard glass form a broad, single-peaked distribution around the true density, indicating the bimodal distribution observed for the cosmic dust is not an artifact of the analysis technique.

Fraundorf et al. (3) employed an entirely different density determination technique, measuring the particle mass directly on a quartz fiber "balance" and the volume from SEM photographs at a variety of angles. Zolensky et al. (7) have also reported densities of 7 cosmic dust particles using essentially the same technique we have employed, though they infer the Fe mass by neutron activation. Though neither group measured densities on a sufficient number of particles to observe the bimodal distribution, when the results of both laboratories are added to our determinations (Figure 2) the bimodal distribution remains, and the peaks are shifted only slightly (to 0.6 gm/cc and 1.9 gm/cc). The survival of the bimodal distribution in the combined data from the three laboratories strongly suggests the existence of two distinct density groups of stony micrometeorites.

The factor of 3 difference between the mean densities of the two groups would give rise to a factor of three difference in the Poynting-Robertson orbital evolution rates. This might provide a natural density segregation mechanism, with slower evolving, high density particles being subjected to gravitational resonances more easily than low density ones. The high density particles would also reach significantly higher peak temperatures on atmospheric deceleration than lower density particles with the same entry parameters.

Of the 25 particles shown in Figure 2, fifteen (or 60%) plot in the low density peak. This cannot be taken as a direct indication of the in-space proportions of the two materials. Biases in picking the samples for analysis cannot be excluded, and less dense particles might have a lower chance of surviving atmospheric deceleration intact. In addition, less dense particles would have a lower stratospheric settling rate, causing them to be more concentrated at the collection altitude.

REFERENCES: (1) Sandford, S.A. (1986) Icarus, 68, 377-394. (2) Flynn, G.J. (1989) Icarus, 77, 287-310. (3) Fraundorf, P. et al. (1982) LPS XIII, 225-226. (4) Brownlee, D.E. et al. (1982) LPS XIII, 71-72. (5) Smith, D. et al. (1974), Nature, 252, 101-105. (6) Flynn, G.J. and Sutton, S.R. (1988) Meteoritics, 23, 268-269. (7) Sutton, S.R. and Flynn, G.J. (1989) Meteoritics (abstract) "Density Estimates for Eleven Cosmic Dust Particles Based on Synchrotron X-Ray Fluorescence Analysis" (in press). (8) Zolensky, M.E. et al. (1989), LPS XX, 1255-1256.