REPORT OF THE COSMIC DUST COMMITTEE

C. L. Hemenway, Chairman

The field of cosmic dust is beset with controversy and data that appear to be inconsistent. The writer, an active worker in the field, runs the risk of presenting a somewhat biased viewpoint. He believes that most of the data accumulated over the past ten years are valid, and that the current confusion arises from difficulties with calibration techniques, collection efficiencies, misleading assumptions, optimistic conclusions, and too restrictive a set of theoretical concepts. Significant data have been obtained by upper-atmospheric collections by balloons and rockets, satellite and space-probe detection techniques, studies of microcratering on lunar materials, and zodiacal-light measurements.

Several independent techniques indicate the relative deficiency of particles in the solar system in the mass range from 10^{-7}–10^{-11} g. There are relatively large numbers of particles smaller than 10^{-11} g and considerable numbers of particles heavier than 10^{-7} g. Furthermore, it appears that in near-Earth space and in the upper atmosphere, fluxes of submicron particles are enhanced by a factor of the order of 10^4 over measurements taken beyond the Earth's magnetosphere. The fluxes of submicron dust particles also appear to increase at times by an additional factor of as much as 10^2.

There appears to be little controversy about the solar-system population of dust particles more massive than 10^{-7} g. The satellite-penetration measurements, such as Pegasus, and lunar microcratering studies (Hartung, *Coll.* **13**) give fairly consistent fluxes of solid-type particles and may only be questioned for conglomerate fluffy particles, which make shallow, easily erasable impact craters, and are unable to penetrate thin films. It is interesting that the *S*-10 experiment (Hemenway *et al.*, 1968) observed one such shallow crater. Few fluffy particles are to be expected in the large-mass range ($> 10^{-7}$ g). Furthermore, few large fluffy particles are observed in the rocket collection experiments in the upper atmosphere.

The principal flux inconsistency in the large-particle size range appears to be associated with the Sesame balloon collections (06.105.058). These experiments involve a balloon-top collection technique in the stratosphere and give particle fluxes $\sim 10^2$–10^3 times the Pegasus fluxes. Most of the Sesame particles are larger than 30 μm (10^{-7} g) and appear in significantly enhanced numbers at times of meteor showers; the size is comparable to that estimated for small fragments produced by photographic meteors. The compositions measured in the large balloon particles (06.015.058; Brownlee and Hodge, 1972) appear to be consistent with those indicated by meteor spectra. Thus, large cosmic-dust particles appear to be debris from meteor fragmentation in the upper atmosphere (ibid.). The balloon collection results of Brownlee and Hodge (ibid.), using an air-pump technique, give lower influxes of large particles than does the Sesame technique, which may be the result of significant differences in collector efficiency. The Sesame technique may have an effective collection area larger than its actual area, and is limited by poor statistics.

The relative cumulative size distribution of the Sesame balloon-top particles is similar in shape to that of the satellite fluxes, but the latter are typically 10^2–10^3 less numerous. Nevertheless, it is interesting to note that the change in slope, in either case, occurs at the same particle size – about 30 μ. This would appear to be consistent with the concept that most of the large ($< 10^{-7}$ g) particles in the solar system are of cometary origin.

The relative deficiency of particles in the intermediate-mass range (10^{-11}–10^{-7} g) in the solar system is indicated by several experiments: satellite-penetration measurements such as the pressurized-cell technique used first on Explorer 16, the relative absence of craters in the diameter range from a few microns to 100 μ in the *S*-10 experiment (Hemenway *et al.*, op. cit.), studies of lunar microcratering (Hartung, op. cit.), studies of the recovered Surveyor parts from the Moon (Cour-Palais *et al.*, 1972), and the relatively low fluxes of particles observed in interplanetary space by a variety of techniques such as Pioneer 8 and 9 (Berg and Grün, 1972).

In the smallest mass range studied thus far the data become most uncertain. Originally, the rocket collection experiments of the Luster program failed to collect significant numbers of particles in the mesosphere. However, the work of Kornblum (04.105.066) indicates that large rocket collectors are likely to have low collection efficiencies, particularly at the lower altitudes where the greatest number of particles are to be found. Using flip-out arms of narrow cross section, the Luster instrument collected numbers of particles comparable to the Pandora collector, and the inconsistency between these techniques appears to have been resolved. The development of the in-flight shadowing technique (05.105.049; Skrivanek *et al.*, 1970) has proved the reliability of rocket collections for identification and study of cosmic dust entering the upper atmosphere.

The plasma detector technique, developed in its most sensitive form by Fechtig, has been used in rockets to measure the impact velocities of the submicron cosmic dust. This work has clearly shown that the dust particles in the upper atmosphere (70–120 km) are all falling with velocities that increase with altitude of detection, thus confirming their extraterrestrial origin (Rauser and Fechtig, 1972a). This work has also provided an interesting explanation of the origin of noctilucent clouds as being the result of condensation on incoming cosmic dust. The Pandora collection experiments during noctilucent clouds also show an approximately constant flux of collected dust with altitude, thus indicating independently an extraterrestrial origin for the cosmic dust and the noctilucent-cloud-particle nuclei. The existence of the falling dust particles in the upper atmosphere has been further confirmed by simultaneous observations by Pandora collection, plasma detection, microphone detection, and photometric detection during the same rocket flights (Hallgren and Hemenway, 1972; Lindblad *et al.*, 1972; Rauser and Fechtig, 1972b).

Photometric observations from an orbiting polar satellite (Donahue *et al.*, 1972) have shown the existence of a polar enhancement in the upper-atmosphere dust influx. This high-latitude enhancement is also indicated by rocket collection data that have found little influx of submicron cosmic dust in the equatorial regions (Brazil) (Skrivanek, private communication), greater influxes at intermediate latitudes (New Mexico, USA) (06.105.056), and the greatest influxes at high latitudes (Northern Sweden) (Hallgren and Hemenway, op. cit.).

It appears that the influx of submicron particles generally observed by upper-atmosphere rocket collections is of the order of 10^4 that observed in deep space by Pioneers 8 and 9 and may at times be as large as 10^6 during strong noctilucent-cloud displays. Thus the Earth's effective capture cross section for cosmic dust must be very much larger than its geometric cross section. If the particle entry velocities are sufficiently low, a Coulomb drag interaction with the electrons within the magnetosphere can provide the needed capture mechanism. It is interesting that the size most frequently observed in rocket collections is somewhat smaller than that which is small enough to be driven out of the solar system by light pressure and solar-wind drag forces.

It seems unlikely that the majority of these submicron particles can have a cometary origin, since they are are too numerous and their minimum flux rate into the Earth's atmosphere is too constant for known cometary sources. The writer has proposed, after observing an anomalous incidence of high atomic-number, high melting-point elements in individual submicron particles, that most of these particles have come to us from the Sun (Hemenway *et al.*, 1972).

The upper-atmospheric dust can also be usefully studied by high-power laser techniques, as discussed by Poultney (1972). This laser technique is particularly suited to studies of the time variations of the cosmic-dust influx into the upper atmosphere. Measurements by Alexander *et al.* (1972) from a lunar-orbiting vehicle have shown changes in impact rates that correlate with meteor showers.

Studies of lunar materials have provided significant data in the large-mass range and in the intermediate-mass range. However, in the small-mass range ($<10^{-11}$ g), the results reported by different observers seem to be inconsistent. It appears to be difficult to study submicron craters on a rough eroding surface that may have been shielded by a thin coating of lunar dust for an indeterminate time. The results reported by Neukum *et al.* (1972) on dated lunar spherules show clearly the existence of submicron craters and indicate the existence of large number of submicron particles in the solar system. Gault (1972), however, has questioned the existence of submicron particles in the solar system on the basis that they would make the erosion rate of lunar materials too large.

It is anticipated that in the next three years great progress will be made in the understanding of the origins, size distribution, and chemical compositions of the dust particles in the solar system. Zodiacal-light measurements will be made by Elsasser and plasma detector measurements by

Fechtig on Helios, thus giving a view of the dust population of the solar system as one moves in toward the Sun. Currently, Weinberg is carrying out photometry of the zodiacal light onboard Pioneer 10 enroute to Jupiter. This vehicle also carries two cosmic-dust detection experiments: Soberman's Sisyphus and Kinard's multiple pressure-cell experiment. The results of these observations, as well as of those to be made on Pioneer 11, should contribute significantly to the understanding of the dust population in the solar system.

Research in the cosmic-dust field has important implications for astronomy, astrophysics, geophysics, upper-atmospheric physics, and meteorology, and we expect that interest in the information gleaned from the study of cosmic dust will intensify in these fields.

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