INTERPLANETARY DUST

Changes in the Zodiacal Cloud

George J. Flynn

AT present about 4×10^7 kg — 40,000 tonnes — of interplanetary dust from the Zodiacal Cloud falls onto the Earth annually[1]. But has this rate been constant through time? Apparently not, according to evidence presented by K. A. Farley on page 153 of this issue[2].

Farley has measured the concentration of ^{3}He solar ions implanted into interplanetary dust, in an oceanic core spanning the period from 0.19 to 69.27 million years ago. After correction for the varying sedimentation rate, Farley finds two maxima in the ^{3}He concentration, occurring 37 and 50 million years ago. He interprets these maxima as periods when dust accretion was a factor of three higher than the mean over the interval from 10 to 20 million years ago, and a factor of six higher than the minimum value (16 million years ago). These results clearly call into question any assumption that, over the past few billion years, the Zodiacal Cloud has been in a steady state, producing a constant interplanetary dust flux at Earth.

Small interplanetary dust particles spiral rapidly into the Sun because of the Poynting–Robertson effect, a process of orbital decay caused by drag from solar radiation. Larger particles become smaller by erosion or catastrophic collisions. It takes under 100,000 years for a typical particle of 10–20 micrometres in diameter, starting at 3 astronomical units out, to spiral into the Sun. So the interplanetary dust presently accreted by the Earth was emitted from much larger objects in the relatively recent past. A constant source of dust, providing about 9×10^3 kg s^{-1}, is required to maintain the Zodiacal Cloud in a steady state[3].

Until recently, comets were believed to be the main source of resupply. But Kresak[4] showed that the total mass of dust emitted by currently active comets provides only 2 per cent of the necessary amount. Whipple[5] proposed that the present Zodiacal Cloud was generated by comet Encke during an early and much more active phase of its evolution, an implicit acceptance that the Zodiacal Cloud is not in steady state. The discovery of dust bands associated with asteroid families[6], and physical evidence from interplanetary dust collected from the Earth's stratosphere[7], suggested that some of the dust comes from asteroids. But analysis of the dust-band data by Dermott *et al.*[8] indicates that main-belt asteroids contribute only 30 per cent at most. In all, the inadequacy of identified dust sources to maintain the Zodiacal Cloud in steady state supports Farley's observation of a time variation in the accretion rate, and further suggests that we are currently in an era of increased dust flux.

This has implications for the sources of the dust. The slowly eroding surfaces of all asteroids and active comets contribute continuously to the interplanetary dust. But from the large peaks in the dust flux, as reported by Farley, it would seem that one, or only a few, dramatic events, such as the catastrophic disruption of a large asteroid or the appearance of an unusually active comet, contribute the bulk of the dust in times of peak intensity.

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'Zodiacal light' seen after sunset as sunlight reflects off zodiacal dust.

During these periods of higher flux, most of the interplanetary dust should reflect the composition and mineralogy of one or a few parent bodies. The abundance of carbon, which is particularly diagnositic of meteorite type and albedo, has been measured in some 60 stratospheric interplanetary dust particles[9,10]. All have carbon contents greater than the carbonaceous chondrite Allende[9,10], suggesting that they do not span the range of albedos, and inferred carbon contents, exhibited by main-belt asteroids[11,12]. Even the most diverse types of interplanetary dust, the hydrated and the anhydrous particles, may originate from a single parent body[13]. This lack of compositional diversity is consistent with the bulk of the interplanetary dust presently falling onto the Earth being derived from one or a few dramatic events[11,12].

An alternative to Farley's interpretation is that these variations record changes in the solar emission rate of ^{3}He, resulting in higher ^{3}He concentrations in dust particles exposed during peaks in the emission. Examination of lunar samples and meteorites shows no evidence that there is much variation in the solar ion flux, although these measurements are not particularly sensitive to short-term variations of a factor of three or so. So the cause of the ^{3}He spikes at 37 and 50 million years ago must be investigated by other techniques.

If, as Farley proposes, ^{3}He has not diffused from its original site and the record is therefore not distorted, intact interplanetary dust from earlier times should be preserved in the core. Farley calculates a concentration of about 7 parts per million of small (up to 50 micrometre) interplanetary dust particles, and up to 700 p.p.m. of larger particles in the sediment that is richest in ^{3}He. These larger particles should be identifiable by mapping sediment sections for elements rich in chondritic particles, followed by chemical and mineralogical studies on the chondritic regions. If Farley is correct, comparison of the 16- and 37-million-year-old layers will show dust concentrations that vary by a factor of six. Furthermore, in the layers recording peaks in the dust flux, the composition and mineralogy of the dust should reflect that of the parent bodies causing the enhancement.

Farley points out that iridium, which is normally used as a tracer of extraterrestrial matter, does not correlate with ^{3}He. This is because iridium traces the total deposition of extraterrestrial material, whereas ^{3}He traces only those extraterrestrial particles that are small enough (less than 50 micrometres) to accumulate a significant bulk concentration of solar ^{3}He and retain that ^{3}He during entry into Earth's atmosphere. Particles smaller than 50 micrometres constitute about 10 per cent of the total mass of interplanetary dust[1], so Farley's results relate directly to only a small fraction of the interplanetary dust falling onto the Earth. Direct identification of dust particles in the sediments would track the flux of particles over the whole size range. ☐

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1. Love, S. G. & Brownlee, D. E. *Science* **262**, 550–553 (1993).
2. Farley, K. A. *Nature* **376**, 153–156 (1995).
3. Grun, E. *et al. Icarus* **62**, 244–272 (1985).
4. Kresak, L. in *Solid Particles in the Solar System*, IAU Symp. 90 (eds Halliday, I. & McIntosh, J.) 211–222 (Reidel, Dordrecht, 1980).
5. Whipple, F. L. in *Zodiacal Light and the Interplanetary Medium* NASA SP-150 (ed. Weinberg, J. L.) 409–426 (NASA Sci. Tech. Information Office, Washington DC, 1967).
6. Low, F. J. *et al. Astrophys. J.* **278**, L19–L22 (1984).
7. Flynn, G. J. *Icarus* **77**, 287–310 (1989).
8. Dermott, S. F. *et al.* in *Asteroids, Comets, and Meteors 1991* (eds Harris, A. W. & Bowell, E.) 153–156 (LPI, Houston, 1992).
9. Schramm, L. S. *et al. Meteoritics* **24**, 99–112 (1989).
10. Thomas, K. L. *et al.* in *Analysis of Interplanetary Dust* AIP Conf. Proc. 310 (eds Zolinsky, M. E. *et al.*) 165–172 (American Institute of Physics, New York, 1994).
11. Flynn, G. J. *Meteoritics* **28**, 349 (1993).
12. Flynn, G. J. *Planet. Space Sci.* **42**, 1151–1161 (1994).
13. Zolensky, M. E. & Barrett, R. *Microbeam Anal.* **2**, 191–197 (1993).