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## Atmospheric Noble Gases from Extraterrestrial Dust

Schmidt recently discussed (*1*) the effect of varying one of the parameters—the influx rate of extraterrestrial dust—on the intensity of the proposed atmospheric-source mechanism (*2*). His discussion and table provide numerical support of my remark that "The source strength does depend directly on . . . the total influx of extraterrestrial material to the earth." (However, the numbers in the last line of his table 1 are not consistent with each other or with the rest of the table.) His comments further demonstrate the validity of my statement that "Estimates of accretion of extraterrestrial dust vary widely." In fact the papers on (possibly) extraterrestrial spherules that Schmidt himself has cited elsewhere (*3*) show an apparent spread of four orders of magnitude in the reported rate of influx of spherules (seven orders of magnitude if one extremely high value is included). The lowest values (*4*) are based on separations of magnetic spherules from marine sediments, and it is difficult both to evaluate the effects of weathering in the marine environment on the long-term preservation of these spherules and to be sure of the efficiency of experimental separation and identification.

The ratio of extraterrestrial to terrestrial spherules at any particular time and place on the surface of the earth is a matter of active investigation and considerable controversy (*5*), and the observations of Giovinetto and Schmidt that Schmidt cites are relevant. Among spherules of extraterrestrial origin, the relative abundances of atmospheric-ablation droplets from large meteorites, micrometeorites fused during atmospheric entry, and preatmospheric spherules also are not well determined.

I agree with Schmidt that rates of influx of identifiably extraterrestrial spherules may be much smaller than influx rates of other kinds of finegrained material. In fact I noted in my paper that determinations of the number of dark magnetic spherules may have underestimated rates of influx because they did not include water-soluble compounds, silicates, or material volatilized during entry into the atmosphere. The magnetic-spherule estimates also of course do not include influx of nonmagnetic material or of particles sufficiently small, or with low-enough velocity, to have escaped complete melting during atmospheric entry.

It is the rate of total influx of all extraterrestrial material, not the rate of spherule influx, that is the significant rate in determining the source intensity for atmospheric contributions. The spherule measurements were quoted in an attempt to give a lower limit for the rate of total influx. However, in view of the uncertainties mentioned in the original paper and here, some of which Schmidt has reemphasized, it would have been better to omit altogether any reference to studies of spherules.

For the calculation in my paper, I assumed an influx rate of $2 \times 10^{-7}$g cm$^{-2}$ year$^{-1}$, corresponding to about $10^6$ tons per year over the surface of the earth. This value is in fair agreement with several different types of experimental evidence for total annual mass influx from extraterrestrial sources. This evidence includes the following: (i) Microphones and other satellite-borne equipment (*6*) lead to estimated influx rates of $4 \times 10^6$ tons per year, (ii) The total abundance of nickel found in Antarctic ice by Brocas and Picciotto (*7*), most of which they think they can demonstrate to be extraterrestrial in origin, leads them to estimate an influx of cosmic dust of $3 \times 10^6$ tons per year. (iii) The $Cl^{36}$ activity found in marine sediments by Schaeffer *et al.* (*8*) enables them to estimate a minimum influx of extraterrestrial dust of about $10^6$ tons per year, assuming saturation values of $Cl^{36}$. (iv) The $Al^{26}$ activity found in submarine sediments by Lal and Venkatavaradan (*9*) is consistent with an influx of $4 \times 10^6$ tons per year, assuming saturation values of $Al^{26}$ and solar-flare fluxes of 20 protons cm$^{-2}$ sec$^{-1}$ of energy greater than 10 Mev, averaged over the dust-particle orbits.

None of these numbers is of high precision: the satellite estimates depend on assumptions about particle velocities; the other estimates depend on assumptions about the chemical composition of the dust; the estimates based on long-lived radioactivities directly depend on the average lifetimes of the dust grains in space, which may be much shorter than the mean life of $Al^{26}$ or $Cl^{36}$; and the average flux and energy spectra of solar-flare particles throughout a solar cycle are uncertain. Nonetheless, the number that I used for a current rate of influx of extraterrestrial dust is not inconsistent with the available experimental data, and may even be conservatively low.

Regarding the several essential parameters necessary to calculate for specific gases an average input intensity for the atmospheric-source mechanism of "solar wind in dust," it seems probable that uncertainties in the contemporary rate of influx of dust will be greatly reduced in the next few years. The most difficult parameters to establish quantitatively may be the rate of gas loss from the grain surfaces, resulting from the combined effects of diffusion and sputtering, and the rate of influx of dust during the earth's early history.


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