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Abstract

Full Text

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GEOPHYSICS

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EXPERIMENTAL DATA EVIDENCE AGAINST THE HYPOTHESIS OF A DUST CLOUD OF THE EARTH

In many original and review papers devoted to the description and interpretation of experiments on the study of collisions with micrometeors in outer space, it is asserted that direct measurements on rockets, satellites, and spacecraft, carried out over a number of years at various geocentric distances (^{1}, ^{2}), imply the existence around the Earth of the so-called "dust cloud" (^{3}). In 1966 publications appeared in which the validity of such an assertion was called into question.

The most substantial part of the experimental data that led to ideas about the concentration of interplanetary dust in the vicinity of the Earth was obtained with the aid of piezoelectric impact sensors. In work (^{4}), some of the principal types of piezoelectric sensors previously used were studied, and it was established that a common drawback of them is internal noise generated under the influence of temperature changes. The noise level under conditions close to real ones proved to be so high that, in the author' s opinion, all experimental data obtained earlier with the aid of piezoelectric impact sensors cannot be regarded as satisfactory and accepted for consideration.

Doubts as to the validity of the measured values of dust-particle fluxes were also expressed on theoretical grounds. In a series of papers (^{5}), possible mechanisms for the formation of the Earth' s dust belt by capture of interplanetary dust particles were considered, and it was shown that none of these mechanisms is at all effective.

On the artificial Earth satellite "Kosmos 135," placed in orbit on 12 XII 1966, we carried out measurements of the frequency of collisions with micrometeors at altitudes of 260–650 km, likewise by means of piezoelectric sensors, in principle analogous to those used for these purposes earlier by other authors. However, in designing the apparatus, on the basis of the results of preliminary laboratory investigations which showed that, under changes in the temperature regime, the sensors themselves and elements of the construction can serve as sources of spurious signals, we took a number of special measures both to reduce the noise level and to increase the noise immunity of the apparatus.

Two identical instruments were installed on the satellite. Each instrument has two sensors containing a piezoceramic element and a preamplifier. For amplification, the high-frequency component of the signal in the 96–104 kHz band is used. In order to suppress interference of electromagnetic origin, the amplified signals from the two sensors are fed to a coincidence circuit; selection according to signal duration was additionally introduced. The signal amplitude is recorded by a 10-channel amplitude analyzer with a logarithmic scale and a dynamic range of ~100.

The sensors of the first instrument are mounted on a special external panel, well acoustically insulated from the body of the satellite. The total surface area of the panel is 0.48 m^2. The sensors of the second instrument are placed directly on the body. The sensitive surface is ~1 m^2.

The sensitivity of the apparatus was set at such a level that, during temperature tests of the sensors and the assembled panel, no false signals were observed, and the level of electrical and mechanical noise from the satellite equipment lay substantially below the threshold.

In preparing the experiment it was assumed that comparative data from the two instruments would make it possible to estimate the possible contribution of noise of thermal origin arising in elements of the satellite structure, and would be useful in designing subsequent experiments.

The serviceability of each instrument throughout its operation in flight is checked by strictly periodic application of a calibration impact to the sensing surface; the corresponding test signal must pass into a definite channel of the amplitude analyzer.

Laboratory calibration of the sensitivity of the instruments was carried out by dropping calibrated balls with weights from 50 to 2000 μg. The threshold sensitivity, in transmitted impulse, of the first instrument is $6 \cdot 10^{-3}$ dyne • sec, and of the second $7 \cdot 10^{-3}$ dyne • sec. Assuming that the mean velocity at impact is 30 km/sec and that the signal is proportional to the particle impulse, the apparatus should register micrometeors with mass greater than $2 \cdot 10^{-9}$ g.

Proceeding from literature data on the dependence of the frequency of collisions with micrometeors in near-Earth space on the minimum registered mass ([1]), one could suppose that each instrument should, on average, register more than 100 collisions per day. However, the results obtained by us differ sharply from these estimates, which are based on the results of previous investigations.

During the first 140 hours of operation, the sensors placed on the panel did not register a single event. Over the subsequent 120 hours, 35 events were registered; however, the distribution of 34 of them is periodic in time. The period of occurrence of these events, to an accuracy of 4%, is connected with the period of revolution of the satellite around the Earth, and the moments of their appearance themselves are tied to similar portions of the change in the temperature regime of the panel. It is quite obvious that these signals cannot be connected with micrometeor impacts and are the result of the registration of certain interferences arising in the system, most probably "crackles" of thermal origin. We note that the serviceability of both instruments throughout the entire period of operation is confirmed by the results of regularly performed automatic checks.

Of all the registered signals, only one, which passed through the most sensitive channel, does not fit into the periodicity indicated above and may, with some probability, be regarded as the result of a collision.

The sensors of the second instrument, installed directly on the satellite body, registered 205 signals in 150 hours of operation. The distribution of these signals in time is substantially nonuniform; 75% of the events are observed in the period from 12 to 22 hours according to the satellite' s local time, and the greatest counting rate is observed in the region where the satellite enters the Earth' s shadow. The amplitude distribution of the impulses has a spectrum substantially steeper than the spectrum expected for collisions with micrometeors. Thus, the amplitude of only one signal exceeds the value corresponding to an impulse magnitude of $5.3 \cdot 10^{-2}$ dyne • sec. It may be asserted with confidence that the sensors register mainly noise of thermal origin arising in the satellite, and that it is practically impossible to separate from them the very rare signals corresponding to collisions.

It seems to us that this conclusion may to a large extent also apply to earlier experiments, in which no special measures were taken for protection against interference of this kind.

The data obtained by us can be characterized quantitatively by Table 1. The experimental values N given in the table are multiplied by

coefficient 2 to account for shielding by the Earth. The table shows that our data differ by more than 10^3 times from the results obtained previously by other authors using piezoelectric detectors. Even the values of N calculated on the assumption that all recorded signals correspond to collisions with micrometeors are 1–2 orders of magnitude lower than estimates based on literature data.

It is important to note that the estimate we obtained, $N \leqslant 4.6 \cdot 10^{-6}$ particles/$m^2 \cdot s$, corresponding to one possible collision recorded by the sensors of the first instrument, is in good agreement with the data on the frequency of punctures of thin shells of gas-filled cells, wire meshes, and thin capacitors obtained on the satellites "Explorer 16" and "Explorer 23" and "Pegasus 1" and "Pegasus 2" ($^{6-8}$), and eliminates the need for artificial explanations of discrepancies between data on punctures and collisions (^{6,8}).

Table 1

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Instrument	Exposure, $m^2 \cdot s$	Sensitivity, dyne · s	Collision frequency N, $m^{-2} \cdot s^{-1}$, including background noise	Collision frequency N, $m^{-2} \cdot s^{-1}$, without background	Collision frequency N, $m^{-2} \cdot s^{-1}$, calculated from lit. data (1)
No. 1, sensors on the panel	$4.4 \cdot 10^5$	$6 \cdot 10^{-3}$	$1.6 \cdot 10^{-4}$	$4.6 \cdot 10^{-6}$	$6.2 \cdot 10^{-3}$
No. 2, sensors on the body	$5.4 \cdot 10^5$	$7 \cdot 10^{-3}$	$7.6 \cdot 10^{-4}$	–	$4.7 \cdot 10^{-3}$
No. 2, sensors on the body	$5.4 \cdot 10^5$	$5.3 \cdot 10^{-2}$	$3.6 \cdot 10^{-6}$	–	$1.6 \cdot 10^{-4}$

From the data presented the following follows. The use of collision sensors for micrometeors based on the registration of mechanical oscillations requires careful protective measures against disturbances of acoustic, thermal, and electrical origin. On the basis of the results we obtained, and taking into account the results of laboratory studies of the piezoelectric sensors used previously (4), it may be assumed that in the experiments described in the literature the level of disturbances was excessively high, and the reported values for the collision frequency are greatly overestimated and do not correspond to reality.

The existence of a dust cloud around the Earth cannot be considered established. Moreover, the data from our measurements of the collision frequency, in agreement with the data from measurements of puncture frequency, rather testify to its absence.

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Note: Figure translations are in progress. See original paper for figures.

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