COSMIC DUST CATALOG: SOME PRELIMINARY ASTRONOMICAL RESULTS BASED ON STATISTICAL ANALYSES OF CDC DATA

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ABSTRACT. The statistical analysis of cosmic dust and stratosphere contaminants is made on the base of first nine volumes of Cosmic dust catalog published in the NASA Johnson Space Center since 1981. The percentage of all 1005 collected and catalogued particles of true cosmic origin is 27 % and percentage of different kind of contaminants (natural, artificial, questionable, etc.) are evaluated also with respect to shape of examined particles. Some astronomical aspects (questions) are pointed out, which would be useful to solve in the future.

1. INTRODUCTION

Cosmic dust catalog (Clanton et al., 1982a; 1982b; 1982c; 1982d; 1982e; 1983a; 1983b; 1984; McKay et al., 1985; Zolensky et al., 1985; 1986; 1987) published and compiled by Cosmic Dust Preliminary Examination Team (CDPET) is a unique and first presentation of information resulting from the NASA Johnson Space Center (JSC) Cosmic Dust Program.

According to this program since May, 1981 special type of aircraft was used to collect cosmic dust particles directly ("in situ") from Earth's stratosphere at the altitude of about $\sim$18 km. The total number of whole statistical set, i.e. number of collected, examined and catalogued particles

presented in the first nine volumes of the Cosmic Dust Catalog is 1005.

In the presented paper a basic statistical analysis of the whole statistical set (1005 particles) is made and some astronomical aspects are discussed. Some useful technical details and needed additional information on the processing and examination of particles made at the Lyndon B. Johnson Space Center in Houston were compiled also by seven special issues of Cosmic Dust Courier (1982a; 1982b; 1983; 1984a; 1984b; 1985; 1986; 1989).

On the basis of the NASA Cosmic Dust Catalog data or samples were already published several papers, but their theme is not identical with our (e.g. Mackinnon and McKay, 1986; Mackinnon et al., 1987; Walker and Zinner, 1988; Jates et al., 1988; Reitmeijer, 1989; Schramm et al., 1989, Flynn, 1989).

2. COLLECTION TECHNIQUE USED IN NASA-JSC COSMIC DUST PROGRAM

The basic units of the collection technique were flat plate "flags". Each flag has ~ 30 cm^2 surface area and was coated with silicone oil and then flown aboard a NASA aircrafts during a many series of flights across the different regions of U.S. The flags were installed in specially constructed wings pylons which ensured that the necessary level of cleanliness was maintained between periods of active sampling. During successive periods of high-altitude cruise ($\sim$ 18 km), the flags were exposed to the stratosphere by pilot command and then retracted into sealed storage containers prior to descent. In this manner a total of almost seven hundred hours of stratospheric exposure were accumulated. It should be emphasized that cumulative exposure time mentioned above represents summa of some flags only flown and exposed during certain series of flights. For instance, flag marked W7017 was one of eight flags flown aboard a NASA WB 57F aircraft during a series of flights across the western United States from July 7, 1981, to September 15, 1981. From W7017 collection surface were retrieved 104 particles only, for further analysis, after 45 hours exposure time.

CDPET for further analysis of the particles used the spatial particles "mounts", which were designed for the JEOL 100 CX scanning electron microscope (SEM). Each mount consists of a grafite frame (size $\sim$ 3x6x24 mm) onto which a spatial filter was attached. Cosmic dust particles were individually removed from collection flags by means micromanipulators under a binocular stereomicroscope. Each particle was positioned on an aluminium-free area of a freon-cleaned, carbon-coated mount filter and washed in-place with hexane to remove silicone oil.

Each mount was normally limited to 16 particles. In the NASA/JSC conditions, all processing and storage of particles were realized in a Class-100 clean room. Before leaving this room each rinsed particle was examined by electron optical microscope. At a magnification of 500x, some physical characteristics of each particle were determined by CDPET and

recorded in Cosmic Dust Catalog. After this process, a JEOL 100 CX instrument, equipped with PGT 600 solid-stay X-ray analyzer, was used to obtain a secondary electron image and an energy-dispersive X-ray spectrum (EDS) of each particle. Next, each mount was stored in a dry nitrogen gas atmosphere in a sealed cabinet.

The basic information about flags taken into account are presented in Table I. If the number of mounts in a certain flag is known, then it is given in the brackets after the official asign of the corresponding flag. In Table I, the data of series of flights, the duration of collection (cumulative exposure time) expressed in hours, approximate collection location and total number of examined particle are presented also for a given flag.

Table 1

FLAG (No.of mounts)	Collection DATE	Collection DURATION (hours)	Collection LOCATION	NUMBER of examined particles	REMARKS
W7010	May-July 1981	66	N and Centr Am	4	
W7013(8)	May-July 1981	65	W-Centr N Am	124	
W7026	Sep-Nov 1981	28	Western US	2	
W7028	Sep-Nov 1981	31	Western US	7	
W7031	Sep-Nov 1981	28	Western US	6	
W7029(10)	15.9.-2.12.1981	35	Western US	161	1 of 8 flags
W7027(9)	15.9.-2.12.1981	3	Western US	131	1 of 8 flags
W7017(7)	7.7.-15.9.1981	5	Western US	104	1 of 8 flags
U2001(5)	13.3.-8.4.1982	31	E-Centr-W US	89	1 of 2 flags El Chichon eruption
U2011	March-April 1983	35	Mid-W US	8	
U2015(5)	22.6.-18.8.1983	39.6	W coast of N Am	111	1 of 2 flags
W7066	November 1983	33	N Am,N Pacific	4	
W7069	November 1983	33	N Am,N Pacific	3	
W7071	November 1983	33	N Am,N Pacific	4	
U2017	Jul 1983-Feb 1984	39	Western US	11	
U2018	Jul 1983-Feb 1984	39	Western US	6	
U2022(6)	9.4.-26.6.1984	41.8	W-Centr N Am	133	
U2034(6)	April-August 1985	33.7	W-Centr N Am	97	
Total:		691.1		1005	

3. THE CONSIDERED MAIN CHARACTERISTICS OF PARTICLES

SIZE (μm) - was measured using the original SEM image and its known magnification factor. For a irregularly shaped particle, the minimum dimension in the field of view was located and determined; then a second (maximum) dimension was measured at a right angle to the first. For a spherical or equidimensional particle, a single size was recorded only.

SHAPE - of particle may be in generally spherical (marked as S), equidimensional (E), or irregular (I). Particles having intermediate shape between S and E or E and I were devoted as S/E or E/I, etc.

TRANSPARENCY - was determined by optical microscopy. The particles were transparent (T), translucent (TL), or opaque (O).

COLOR - was determined by optical microscopy also. The distinction of dark (Dk) from light (Lt) was unambiguous in spite of changes of color perception with observer. The distinction of colorless (CL) from color particle was reliable also.

LUSTER - was determined by optical microscopy using a combination of different illumination. Commonly applied descriptions, adopted from mineralogical usage, include dull (D), metallic (M), submetallic (SM), vitreous (V) and subvitreous (SV) particles. Lusters transitional between these categories (or difficult to identify surely) were indicated as D/SM, SV/V, etc.

TYPE - was the main characteristic of particle on which was concentrated our study in the presented paper. In the first-order identification of the particle the type indicates a provisional conclusion follows from particles' morphology (according SEM image), elemental composition (from EDS), and optical properties. It must be emphasized that, for Cosmic Dust Catalog purpose, types were defined for their descriptive and curatorial utility not as scientific classification. So, in the quoted volumes of Cosmic Dust Catalog - different "types" were specificated only to aid the users of this Catalog in distinguishing cosmic dust particles from other particles which were invariably collected during cosmic dust sampling. Categorizations are only tentative and reflect judgements based mainly on the collective experience of the CDPET, and should not be construed to be firm identification. In this sense in the Cosmic Dust Catalog were defined hitherto some types of particle as follows:

"AOS" - Aluminium oxide sphere. With high probability AOS (almost ideal spherical particles) represent products of solid fuel rocket exhausts. In its EDS spectrum "Al" was the distinctively dominant peak, sometimes only.

Nonspherical particles with high "Al" abundance were of enigmantic origin and had been provisionally called "Al particles".

"C" - Cosmic dust (variety unspecified). In the Cosmic Dust Catalog type "C" was used to conveniently group together all particles which were supposed to be of extraterrestrial origin, including "large" particles that had apparently experienced strong ablation heating or melting and consequently had many special attributes. Naturally, type "C" includes also micron and submicron particles also, which are called micrometeoroids or micrometeorites, and which refer only to particles physical state which has not been changed during their passage from the interplanetary space to the Earth's surface.

"TCA" - Terrestrial contamination of the artificial or man-made origin. This category probably includes particles produced by or derived from aircraft operation or collector hardware, or possible spacecraft debris. Their physical features and EDS spectra made possible to distinguish this category from others.

"TCN" - Terrestrial contamination of the natural origin. According to morphologies and EDS spectra of most "TCN" particles, they represent with high probability principal components of the stratospheric volcanic ash. This category includes also mineral, rock, or soil from Earth or various biological contaminants such as spores, insect parts, etc.

"?" - Identification uncertain. This category includes particles which do not unequivocally resemble those grouped together as AOS, C, TCA or TCN. So careful examination will be required before they can be reliably identified. Also symbols "AOS?", "C?", "TCA?" and "TCN?" indicate, that classification was done with not high reliability. Similarily was indicated questionable determination of other characteristic of particles as shape (e.g. "E?"), luster (e.g. "SV?"), etc.

4. STATISTICAL ANALYSIS RESULTS OF ALL AVAILABLE DATA

Provisional classification of particles presented above, represents only a first-order attempt to distinguish particles which are probably extraterrestrial in origin from those that are probably contaminants. This classification was made by CDPET according to examination of each particle by both electron microscope and obtained energy-dispersive X-ray spectrum. On the base of this classification after statistical processing of whole set of data we can gain some specific astronomical results. In the first step we were concentrated upon problem of percentage of individual types in the whole set even with respect to shape of particles. The main results of this analysis are presented in Table 2.

Table 2

Part. TYPE	Abs.NUMBER of part.	Corresp. PERCENTAGE	NUMBER of different particle's SHAPE in the individual types					
			I	I?	S	S?	E	E?
C	274	27	227	7	25	3	8	4
C?	116	12	78	0	30	3	3	2
TCA	96	10	64	0	18	1	12	1
TCA?	90	9	57	1	16	3	7	6
TCN	84	8	75	0	2	1	5	1
TCN?	36	4	30	1	2	1	2	0
AOS	150	15	6	0	138	3	1	2
AOS?	5	0	0	0	2	1	1	1
?	154	15	97	8	39	1	4	5
Total:	1005	100	634	17	272	17	43	22

5. CONCLUSIONS AND DISCUSSION OF THE RESULTS

From our statistical analysis summarized in Table 2 it is possible to draw the following basic conclusions:

A - What concerns the reliability of type determinations and shapes of particles by CDPET (it follows simply from Table 2)

a - With high reliability type was determined for 60 % of all examined particles (1005), i.e. for 604 particles. Other determinations were questionable (i.e. C?; TCA?; TCN?; AOS?) or were unknown at all (?).

b - The shape was classified with uncertainty for 56 particles only (6 %). For other particles (949) the determinations were reliable (94 %).

B - What concerns the percentage of individual types in the whole set or relative number of particle in the types with respect to particles' shape.

c - The percentage of particles with true cosmic origin (type "C") in whole statistical set (1005 particles) is 27 % (274 particles). If we are considering also type "C?" (116 particles), percentage of corresponding type ("C+C?") increases to 39 % (390 particles).

d - Percentage of "TCA" particles in the same whole statistical set is 10 % (96 particles) and "TCA?" particles 9 % (90 particles).

e - "TCN" particles represent 8 % (84 particles) of all examined particles. Together with questionable type "TCN?" (36 particles), this percentage increases to 12 % (120 particles) only.

f - Type "AOS" represent 15 % (150 particles) of all examined particles. The percentage of "AOS?" type was negligible (only 5 particles).

g - The origin of 154 particles (15 %) was not specificated at all (type "?").

h - The percentage of irregularly shaped particles (shape I) decreases from roughly 88 %for "TCN" type particles, 80 % for "C" particles, 68 % for "?" particles, 65 % for "TCA" particles to 4 % for AOS type particles.

i - The highest percentage of spherically shaped particles (S) is evidently among the AOS type particles (93 %). Corresponding percentage is 25 %, 20 %, 16 % and 4 % for types "?", "TCA", "C" and "TCN", respectively.

j - Equidimensionally shaped particles (E) are most presented in the TCA type (14 %). Only 7, 6, 5 and 3 % is the percentage for "TCN", "?", "AOS" and "C" type particles, respectively.

Generally speaking the reliable identification and scientific classification of cosmic dust are two of many important research tasks on the wide field of the cosmic dust problems. From this point of view the reliable determination of the stratospheric dust particles collected in NASA JSC is also very important task. Unfortunately the precise laboratory identification of each particle is often beyond the scope, intent and also possibilities of NASA CDPET and in the present time beyond the scope and possibilities (mainly instrumhetal) of the authors of the presented paper. The statistical analysis of data however clearly shows the necessity of great part of work for reliable determination of the particles' origin (see e.g. conclusion Aa). Moreover the same statistical analysis with connection to facts following from SEM images, EDS spectrum, flights trajectories, etc.), allows to make preliminary conclusions about some astronomical questions as

- sedimentation rate of the volcanic ash on the Earth's surface due to such events like eruption of El Chichon vulcano in Mexico in 1982;

- evaluation of the influx of cosmic dust material on Earth and its possible seasonal variations;

- density of the cosmic dust envelope of the Earth;

- level and variations of natural and artificial contamination in stratospheric layer;

etc.

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