

COSMIC DUST CATALOG

(PARTICLES FROM 13 COLLECTION FLAGS)

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(Particles from 13 Collection Flags)

Compiled by

Cosmic Dust Preliminary Examination Team (CDPET)*

NASA/Johnson Space Center
Houston, Texas 77028 U.S.A.

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*In alphabetical order:

D.S. McKay¹
L.S. Schramm³
K.L. Ver Ploeg³
J.L. Warren²
L.A. Watts²
*M.E. Zolensky¹

¹NASA/Johnson Space Center, Houston, Texas 77058

²Northrop Services, Inc., P.O. Box 34416, Houston, Texas 77234

³Lockheed Corp., 1830 NASA Road 1, Houston, Texas 77058

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1. INTRODUCTION

Since May, 1981, the National Aeronautics and Space Administration (NASA) has used aircraft to collect cosmic dust (CD) particles from Earth's stratosphere. Specially designed dust collectors are prepared for flight and processed after flight in an ultraclean (Class-100) laboratory constructed for this purpose at the Lyndon B. Johnson Space Center (JSC) in Houston, Texas. Particles are individually retrieved from the collectors, examined and cataloged, and then made available to the scientific community for research. Cosmic dust thereby joins lunar samples and meteorites as an additional source of extraterrestrial materials for scientific study.

This catalog summarizes preliminary observations on some of the particles retrieved from 13 collection surfaces. These surfaces consisted of flat plate "flags" (each with $\sim 30 \text{ cm}^2$ surface area) which were coated with silicone oil and then flown aboard NASA WB-57 and U-2 aircraft during a series of flights that were made mostly along the west coast of North America from 1981 to 1984. More complete details regarding these flags are given below. The flags were installed in specially constructed wing pylons which ensured that the necessary level of cleanliness was maintained between periods of active sampling. During successive periods of high-altitude (20 km) cruise, the flags were exposed in the stratosphere by pilot command and then retracted into sealed storage containers prior to descent.

In the previous five Cosmic Dust Catalogs particles were presented from five individual collection surfaces. This catalog will depart from the usual format in that it principally represents a resampling of particles which are believed to be truly cosmic in origin. Thus, this catalog principally contains descriptions of additional fragments of large chondritic particles

from which other fragments have previously been removed, characterized, and allocated. It is hoped that this resampling will facilitate increased interdisciplinary work on interesting chondritic particles. This catalog contains descriptions of 32 additional fragments of chondritic particles from collection surfaces W7010, W7026 (previously sampled for Cosmic Dust Courier 1 -CDCr 1), W7028 (CDCr 1), W7029 (previously sampled for Cosmic Dust Catalog 2 -CDC 2), W7031 (CDCr 1), W7066 (CDCr 5), W7069 (CDCr 5), W7071 (CDCr 5), U2011 (CDCr 5), and U2015 (CDC 5 & CDCr 5). In addition, 7 chondritic particles are described from three new collection surfaces, these being U2017, U2018, and U2022. Finally, descriptions of 32 other interesting particles encountered during the particle sampling of these flags are included to round out the contents of the catalog.

Flight information for each of the flags sampled for this catalog appear in the table below.

<u>Flag</u>	<u>Collection date</u>	<u>Collection duration</u>	<u>Collection location</u>
W7010	May to July, 1981	66 hours	N. and Central America
W7026	Sept to Nov, 1981	28	Western U.S.
W7028	Sept to Nov, 1981	31	Western U.S.
W7029	Sept to Nov, 1981	28	Western U.S.
W7031	Sept to Nov, 1981	28	Western U.S.
W7066	November 1983	33	N. Amer., N. Pacific
W7069	November 1983	33	N. Amer., N. Pacific
W7071	November 1983	33	N. Amer., N. Pacific
U2011	March to Apr, 1983	35	Mid-Western U.S.
U2015	June to Aug, 1983	40	Northwestern U.S.
U2017	July '83- Feb '84	39	Western U.S.
U2018	July '83- Feb '84	39	Western U.S.
U2022	Apr to June, 1984	42	West Central U.S.

2. PROCESSING OF PARTICLES

Particle mounts designed for the JEOL-100CX scanning transmission electron microscope (STEM) are currently the standard receptacles for CD particles in the JSC laboratory. Each mount consists of a graphite frame (size ~3x6x24 mm) onto which a NucleoporeTM filter (0.4- μ m pore size) is attached. A conductive coat of carbon is vacuum evaporated onto the mount and then a microscopic reference pattern is "stenciled" onto the carbon-coated filter by vacuum evaporation of aluminum through an appropriately sized template. CD particles are individually removed from collection flags using glass needle micromanipulators under a binocular stereomicroscope. Each particle is positioned on an aluminum-free area of a Freon cleaned, carbon-coated filter and washed in place with hexane to remove silicone oil. Each mount is normally limited to 16 particles. All processing and storage of each particle is performed in a Class-100 clean room.

3. PRELIMINARY EXAMINATION OF PARTICLES

Each rinsed particle is examined, before leaving the Class-100 clean room processing area, with a petrographic research microscope equipped with transmitted, reflected and oblique light illuminators. At a magnification of 500X, size, shape, transparency, color, and luster are determined and recorded for each particle.

After optical description, each mount (with uncoated particles) is examined by scanning electron microscopy (SEM) and X-ray energy dispersive spectrometry (EDS). Secondary-electron imaging of each particle is performed with a JEOL-100CX STEM operated in the SEM mode and at an accelerating voltage of 40 kV. Images are therefore of relatively low contrast and resolution due to deliberate avoidance of conventionally applied conductive coats (carbon or gold-palladium) which might interfere with later elemental analyses of particles. EDS data are collected with a JEOL-35CF SEM equipped with a Si(Li) detector and PGT-4000T analyzer. Using an accelerating voltage of 20 kV, each particle is raster-scanned and its X-ray spectrum recorded over the 0-10 keV range by counting for 100 sec. No system (artifact) peaks of significance appear in the spectra.

It should be pointed out that the SEM/EDS procedure used in preparing this catalog is different than that used in preparing Cosmic Dust Catalogs, Volumes 1, 2, and 3. In the earlier catalogs, both SEM imaging and EDS analysis were performed using the JEOL-100CX STEM operated at 40 kV. The procedure used for this catalog retains the superior imaging capability of the JEOL-100CX but incorporates the superior EDS capabilities of the JEOL-35CF. The new, two-step process provides the best possible preliminary-quality data while minimizing the electron beam exposure experienced by the samples. Only the EDS spectra exhibit differences that are likely to be

noticed. However, spectra of selected comparison standards that were published in previous catalogs were re-collected under the new procedure and are included in this catalog. Please refer to Section 5 for a more complete discussion.

Following SEM/EDS examination, each particle mount is stored in a dry nitrogen gas atmosphere in a sealed cabinet.

4. CATALOG FORMAT

Each page in the main body of the catalog is devoted to one particle and consists of an SEM image, an EDS spectrum, and a brief summary of preliminary examination data obtained by optical microscopy. The unique identification number assigned to the particle appears at the top of the page. Sources of the descriptive data are as follows:

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

SHAPE is generalized to be spherical (S), equidimensional (E), or irregular (I). Particles having shape intermediate between S and E, or E and I, are not uncommon and may be denoted as S/E or E/I, etc.

TRANSPARENCY (abbreviated TRANS.) is determined by optical microscopy to be transparent (T), translucent (TL), or opaque (O). Significant variations in transparency within a particle are annotated on the SEM image.

COLOR is determined by optical microscopy using oblique (fiber-optic, quartz-halogen) illumination supplemented with normal reflected (tungsten-lamp) illumination. The distinction of dark (Dk.) from light (Lt.) particles is unambiguous, although the distinction of colorless (CL) from pale-colored conditions is sometimes problematical. Complex colorations of individual particles may be noted in the "COMMENTS" column and annotated on the SEM image.

LUSTER is determined by optical microscopy using reflected normal (tungsten-lamp) illumination and supplemented with oblique (fiber-optic, quartz-halogen) illumination. Commonly applied descriptions, adopted from

mineralogical usage, include dull (D), metallic (M), submetallic (SM), subvitreous (SV), and vitreous (V). Lusters transitional between categories or difficult to identify are indicated accordingly (D/SM, SV/V, etc.).

TYPE indicates a provisional first-order identification of each particle based on its morphology (from SEM image), elemental composition (from EDS spectrum), and optical properties. We emphasize that, for catalog purposes, types are defined for their descriptive and curatorial utility, not as scientific classifications. These tentative categorizations, which reflect judgements based on the collective experience of the CDPET, should not be construed to be firm identifications and should not dissuade any investigator from requesting any given particle for detailed study and more complete identification. In the absence of any generally accepted taxonomy for stratospheric dust, the precise identification of each particle in our inventory is beyond the scope and intent of our collection and curation program. Indeed, the reliable identification and scientific classification of cosmic dust is one of many important research tasks that we hope this catalog will stimulate. We indicate particle "TYPE" only to aid the users of this catalog (especially those new to small-particle analysis) in distinguishing possible cosmic dust particles from other particles which are invariably collected during stratospheric dust sampling. In this catalog, particles are organized according to their type. Categories used in this catalog are defined as follows:

AOS: Aluminum oxide sphere. An AOS is transparent, subvitreous to vitreous in luster, colorless to pale yellow and at least approximately spherical. However, shape may range from nearly perfect sphericity to pronounced ellipticity and surface texture may range from very smooth to rough. Other spheres or

irregularly shaped material may be attached to its surface. Al is the distinctively dominant (or only) peak in its EDS spectrum. A sphere displaying the attributes of an AOS except with major elements in addition to Al may be listed as "AOS?" or "?". Transparent Al-rich particles of irregular shape would probably be listed as "TCA?". (AOS particles are products of solid-fuel rocket exhausts.)

C: Cosmic dust (variety unspecified) or other extraterrestrial material. In the strict sense, "cosmic dust" refers only to those particles which have not been modified during passage from interplanetary space to Earth's stratosphere. In this catalog, though, particle type "C" is used to conveniently group together all particles which are judged to be of extraterrestrial origin, including those that have apparently experienced strong ablatational heating or melting. Type "C" particles are provisionally identified as those having one of the three following sets of attributes:

- (a) irregular to spherical, opaque, dark-colored particles composed mostly of Fe with minor Ni or S.
- (b) irregular to spherical, translucent to opaque, dark-colored particles containing various proportions of Mg, Si, and Fe with traces of Al, Ca, S, or Ni.
- (c) irregular to faceted or blocky, transparent to translucent particles containing mostly Mg, Si, and Fe but with traces of Al or Ca.

Category (a) and (b) particles commonly display either complex, porous aggregate type morphologies or distinctively spherical

shapes and dull to metallic lusters which distinguish them from terrestrial minerals. Their EDS spectra are reminiscent of those exhibited by meteoritic Fe-Ni or FeS minerals, or combinations of Fe-Ni-S phases with olivine and/or pyroxene. Category (c) particles display morphologies and EDS spectra which suggest that they are fragments of olivine or pyroxene crystals, neither of which are significant components of stratospheric volcanic ash. Particles which do not fall easily into categories (a), (b), or (c) but which possess some of the same attributes may be classified here as "C?".

TCA: Terrestrial contamination (artificial or man-made). Particles included in the "TCA" category are commonly irregular in shape (though a few may be spherical) and may be transparent, translucent, or opaque. Their EDS spectra commonly show Al, Fe, or Si as the principal peaks but with a variety of minor peaks including those of Ti, V, Cr, Mn, Ni, Cu, or Zn and at abundances which are frequently much greater than those expected in common minerals. However, such compositions are similar to those expected for certain metal alloys. In some cases, a high intensity (relative to intensities of characteristic X-ray peaks) of continuum radiation occurs in the EDS spectrum, suggesting that low atomic number elements not detectable by the EDS (e.g., H, C, N, O) are abundant in the particle. Such "TCA" particles are tacitly inferred to be synthetic carbon based materials. (This category probably includes particles produced by or derived from aircraft operation or collector hardware, or possibly spacecraft debris.

However, some of these particles are worthy of additional research and may represent true extraterrestrial "low Z" material).

- TCN: Terrestrial contamination (natural). "TCN" particles may be transparent to opaque and may exhibit a variety of colors. However, they are commonly irregular in shape and distinctively rich in Si and Al with minor abundances of Na, K, Ca, or Fe. Morphologies and EDS spectra of most "TCN" particles compare favorably with respective properties of silica polymorphs, feldspar, or silicic volcanic glass, three materials which are principal components of stratospheric volcanic ash. In addition, platy or porous aggregate-type particles of light color and Si, Al-rich composition may be silicic clay minerals, common phases in Earth's surface soils. Irregular, reddish Fe rich particles may also be products of terrestrial rock weathering. Recognition of these and other phases as "TCN" particles is based mostly on CDPET's collective mineralogical experience and comparison with reference samples. Less commonly, the "TCN" category may include distinctive particles with apparently non-random shapes which are rich in low atomic number elements (as inferred from their EDS spectra having high levels of continuum X-radiation and relatively small peaks for characteristic X-rays). Those rare particles are distinguished from "TCA" particles by their unusual, organized morphologies and probably represent biological contaminants.
- ?: Identification uncertain. This category includes particles which do not unequivocally resemble those grouped together as

AOS, C, TCA, or TCN. In addition, the "?" symbol is liberally used to reiterate the tentative identifications of other types of particles.

Again, this system for provisional classification of particles is presented only as a first-order attempt to distinguish particles which are probably extraterrestrial in origin from those which are probably contaminants. Many particles, especially those cataloged as type "?", will require careful research examination before they can be satisfactorily identified.

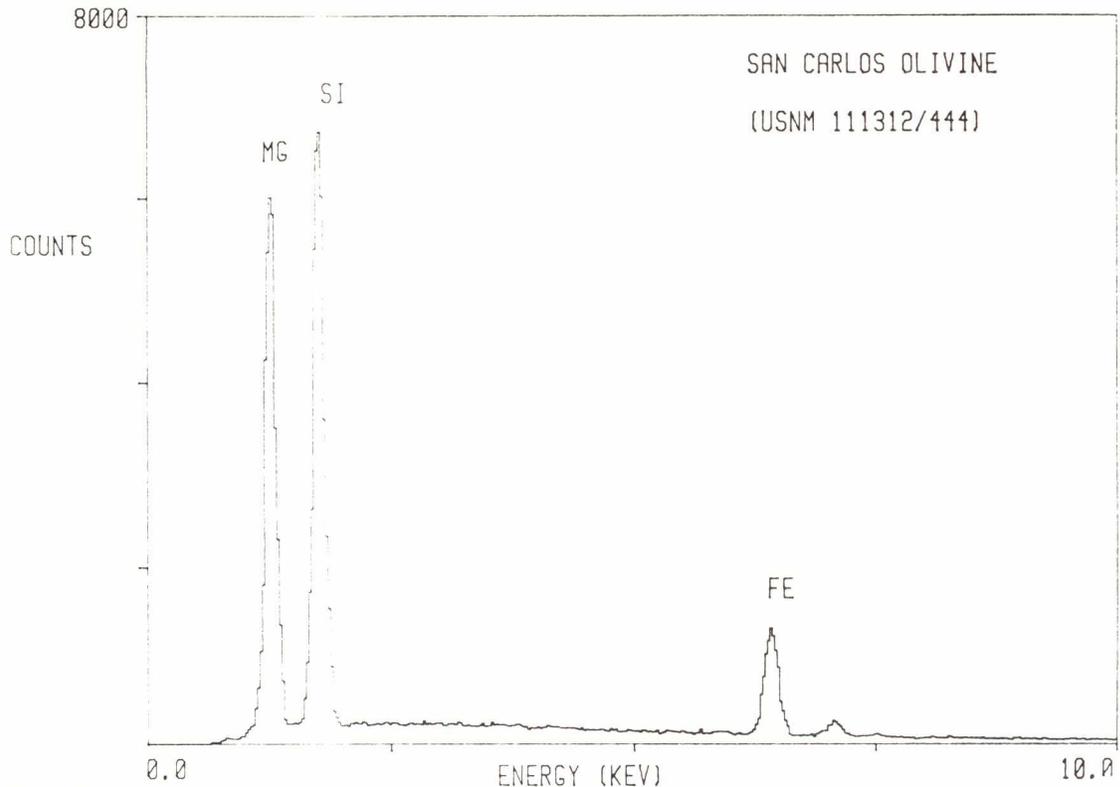
COMMENTS are included for particles with special features or histories. Particles lost during or after preliminary SEM examination, or particles with possible genetic relationships to other particles are noted here.

5. ANALYSES OF REFERENCE MATERIALS

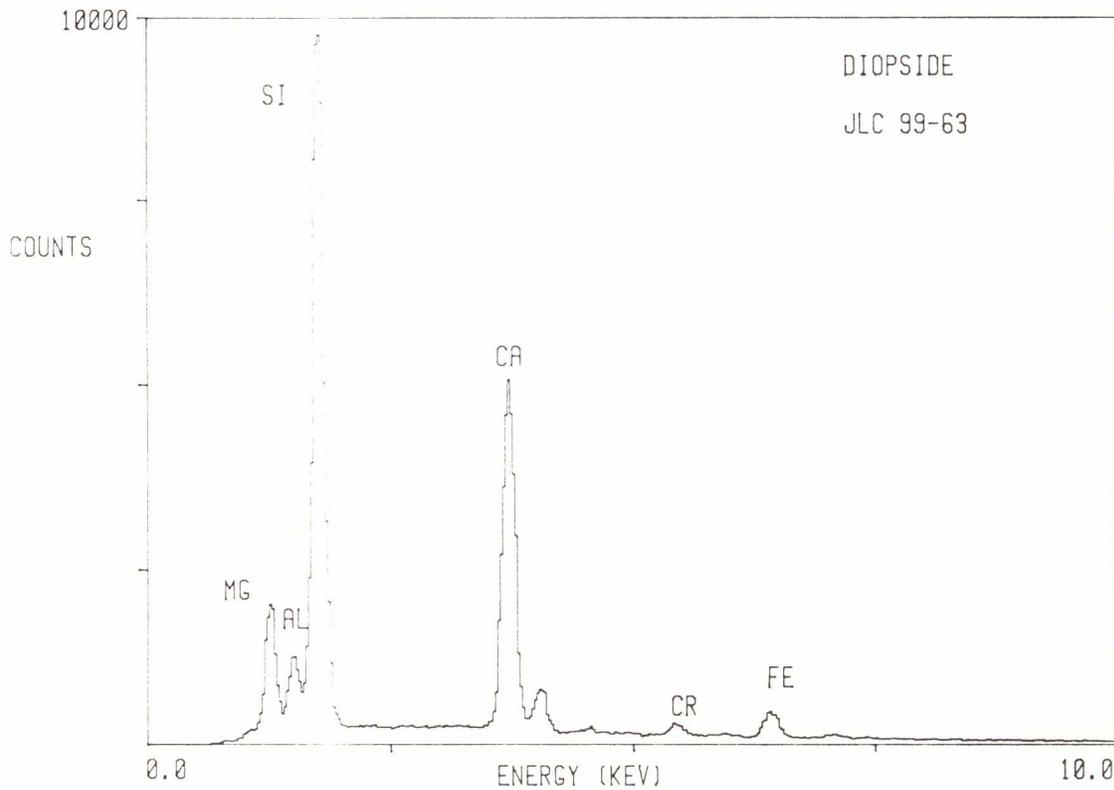
The usefulness of the SEM images and EDS spectra provided for particles in this catalog is enhanced by comparison with similar data products obtained for mineral standards of known composition. Accordingly, a typical EDS spectrum is presented for each of three standard minerals prepared as polished grain mounts (San Carlos olivine, USNM 111312/444; diopside JLC-99-63; Kakanui hornblende, USNM 143965). Analyses of these optically flat surfaces eliminate inter-sample geometrical variations so that effects of detection limits and compositional variations, in general, on relative peak heights in the raw spectra can be more readily assessed. Even so, the polished grain spectra should not be over interpreted because no corrections have been attempted for atomic number, absorption, or fluorescence effects. The spectra are presented simply as additional aids to the meaningful use of the sample particle EDS spectra. Investigators who might wish to compare performance characteristics of their EDS analytical systems with those of the system used by CDPET in preparing these catalog data should contact Curator/Cosmic Dust at the address given in Section 6. A short term loan of a polished grain mineral standard can then be arranged.

As pointed out in Section 3, the EDS spectra included in this catalog were obtained using a primary electron energy of 20 kV whereas spectra in Catalogs 1, 2, and 3 were obtained with a different instrument operated at 40 kV. Although the effects on EDS spectra to be expected from such a change are well known from X-ray spectrometric analysis, they are worth pointing out to avoid confusion among the readers of this catalog. The major effects of concern to Cosmic Dust Catalog users can be seen by comparing the two "Allende (C3) Meteorite Bulk Powder" spectra, one of which was obtained at 20 kV and the other at 40 kV, as presented in Cosmic Dust Catalogs 4 or 5

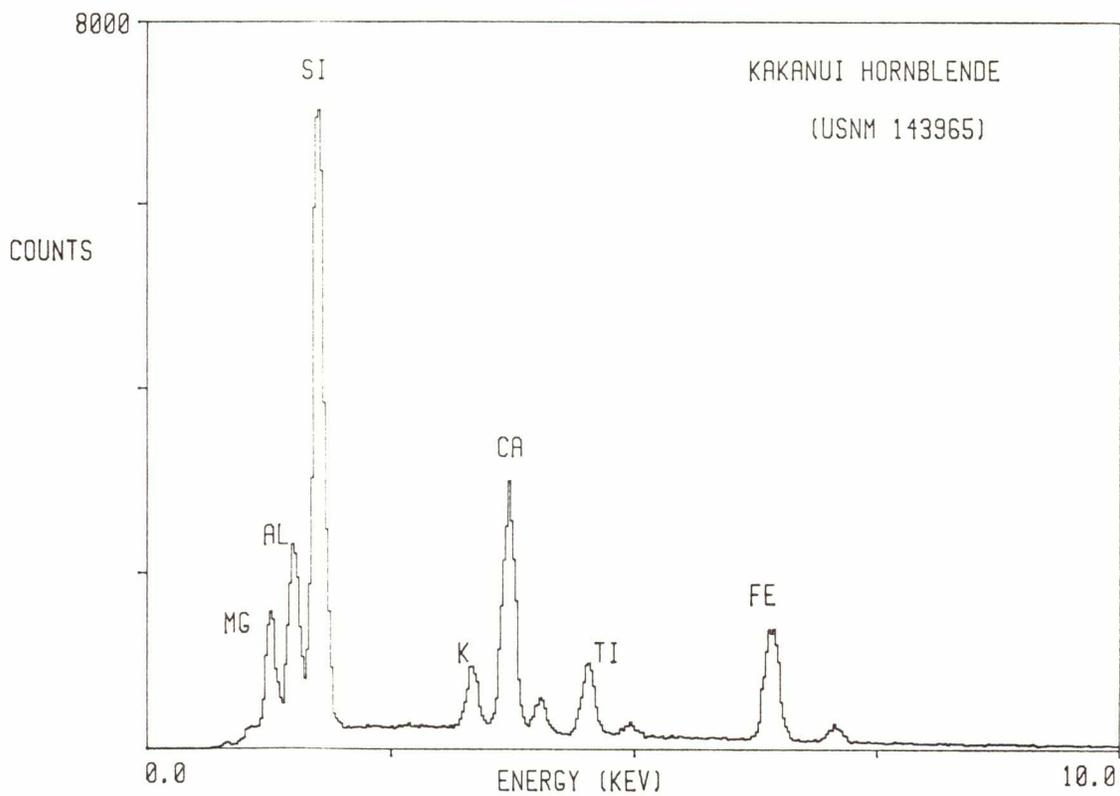
(only spectra collected at 20kV are presented in this catalog). In the 20 kV spectrum, the Si peak is more intense than the principal peak of Fe whereas the opposite is true for the 40 kV spectrum. In general, the 20 kV spectra in this catalog will show peaks of light elements enhanced relative to peaks of heavy elements when compared with 40 kV spectra published in Catalogs 1, 2, and 3. The explanation is based both on geometrical differences between X-ray paths in the two EDS systems (the JEOL-35CF system is actually more favorable for light element analysis) and on electron and X-ray physics (X-ray emission by heavy elements is more intense at 40 kV than at 20 kV). Thus, readers are cautioned against attempting to quantitatively intercompare 20 kV spectra in this catalog with 40 kV spectra in previous catalogs. Still, the spectra in each catalog should continue to serve as originally intended. Namely, the sample and standard spectra in any given catalog will represent a self-consistent data set.



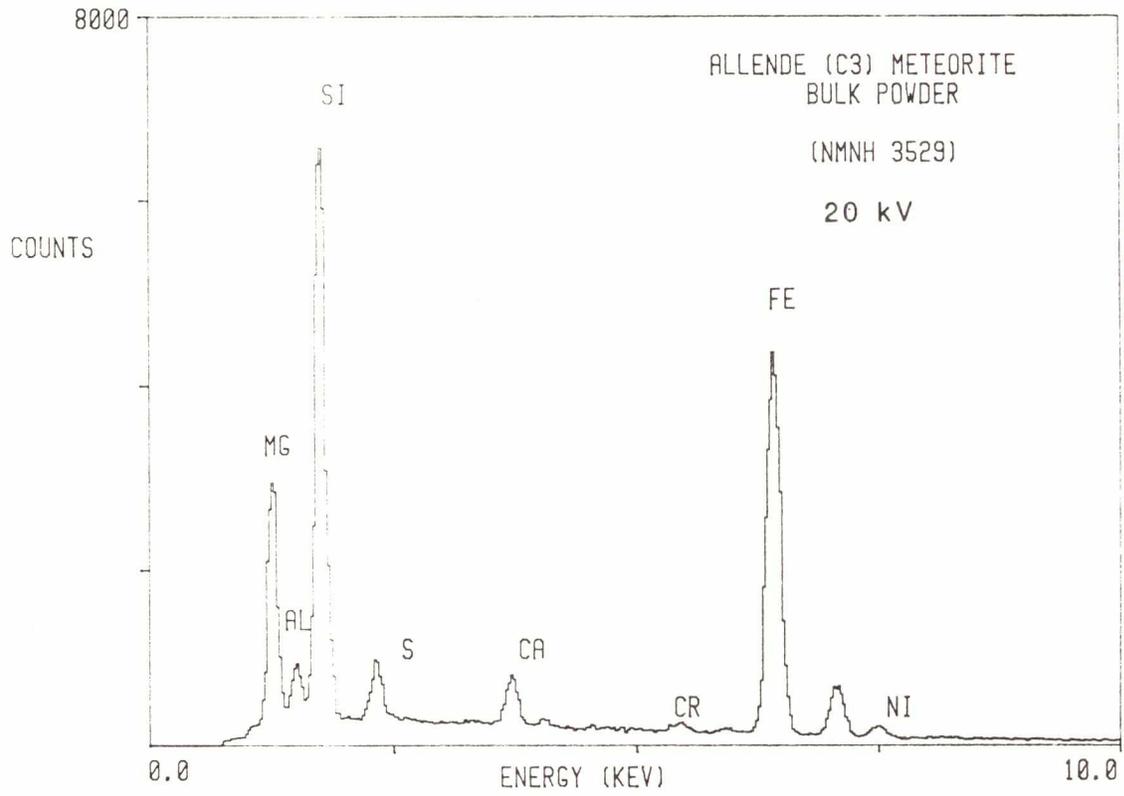
WEIGHT %		Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	NiO	MnO	MgO	CaO	Na ₂ O	K ₂ O	H ₂ O	TOTAL
SiO ₂	TiO ₂	-	-	-	9.55	0.37	0.14	49.42	<0.05	-	-	-	100.29
40.81	-												



WEIGHT %		Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	NiO	MnO	MgO	CaO	Na ₂ O	K ₂ O	H ₂ O	TOTAL
SiO ₂	TiO ₂	6.31	9.96	1.80	2.34	0.04	0.07	16.05	19.64	1.39	-	-	99.99
51.93	0.46												



WEIGHT %													
SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	NiO	MnO	MgO	CaO	Na ₂ O	K ₂ O	H ₂ O	TOTAL
40.37	4.72	14.90	-	3.30	7.95	-	0.09	12.80	10.30	2.60	2.05	0.94	100.02



WEIGHT %											
SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	C
34.23	0.15	3.27	0.52	27.15	0.18	24.62	2.61	0.45	0.03	0.23	0.29
FeS	NiS	CoS	Fe ⁰	Ni ⁰	Co ⁰	TOTAL					
4.03	1.60	0.08	0.17	0.36	0.01	99.98					

6. SAMPLE REQUESTS

Scientists desiring to perform detailed research on particles described in this catalog should apply in writing to:

Curator/Cosmic Dust	Telephone: (713) 483-6241
Code SN-2	or -3274
NASA/Johnson Space Center	FTS: 525-6241
Houston, Texas 77058	or -3274
U.S.A.	

Sample requests should refer to specific particle identification numbers and should describe the research being proposed as well as the qualifications and facilities of the investigator making the request. Additionally, requests for particles not yet passed through preliminary examination will be considered if the requester can demonstrate a strong need for them. NASA will arrange for a review of the scientific merits of each request and will inform the requester of the results. Approval of a sample request does not imply or include funding for the proposed research. Questions about NASA funding should be directed to:

Dr. Donald D. Bogard
Discipline Scientist
Planetary Materials and Geochemistry Program
Code SN-4
NASA/Johnson Space Center
Houston, TX 77058

Although foreign scientists are welcome to request samples, NASA cannot provide funds to be spent outside the U.S.A. by citizens of other countries.

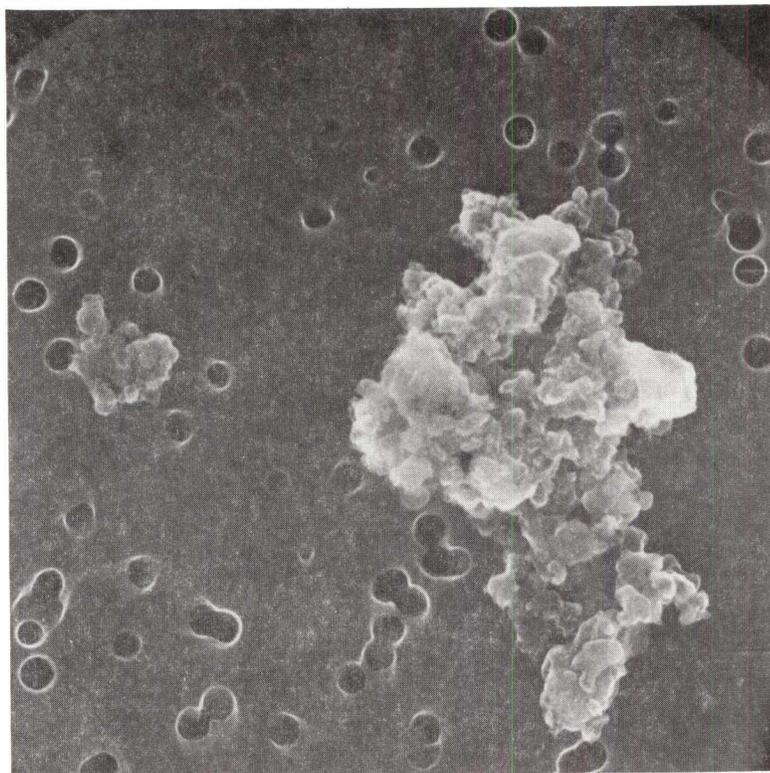
7. ACKNOWLEDGEMENTS

Guy V. Ferry and co-workers (NASA/Ames Research Center, Moffett Field, California) performed the loading and unloading of the cosmic dust collectors on the U-2 aircraft and provided flight log data.

Eugene Jarosewich (Smithsonian Institution, Washington, D.C.) kindly provided mineral standards and the Allende chondrite powder.

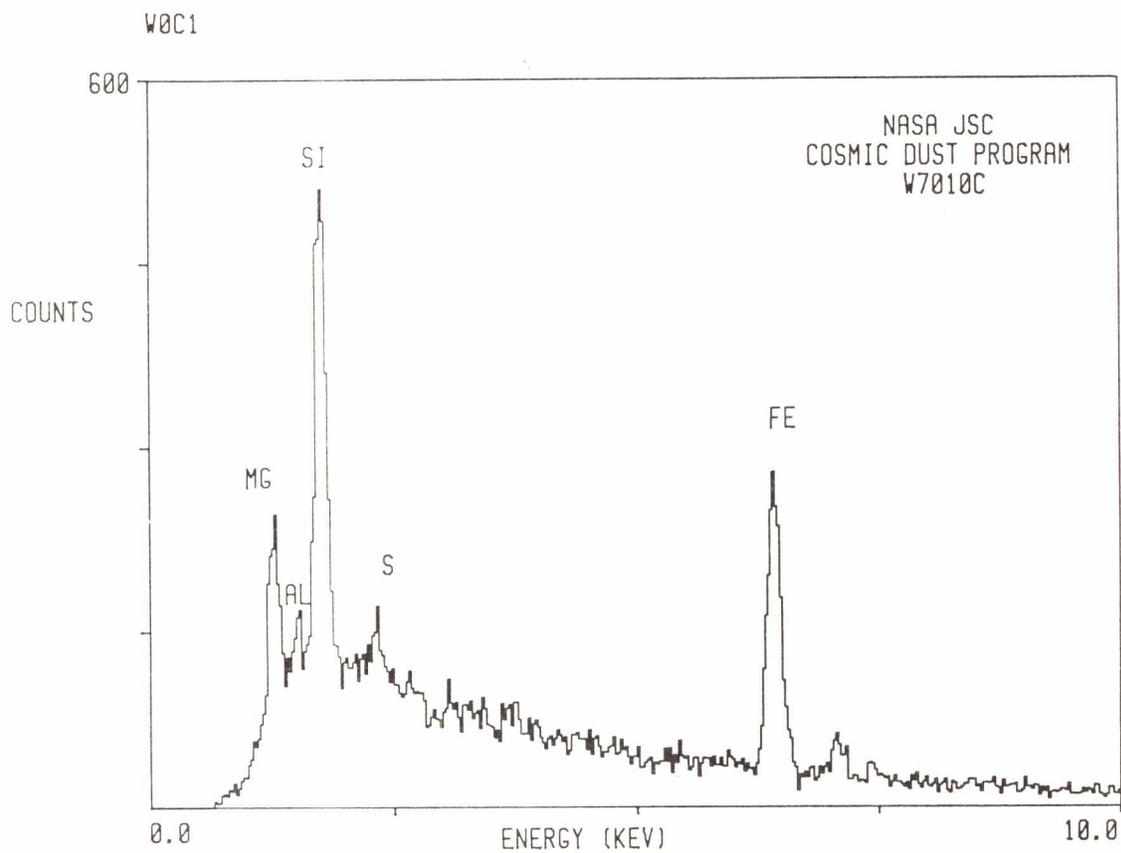
COSMIC DUST

W7010C1

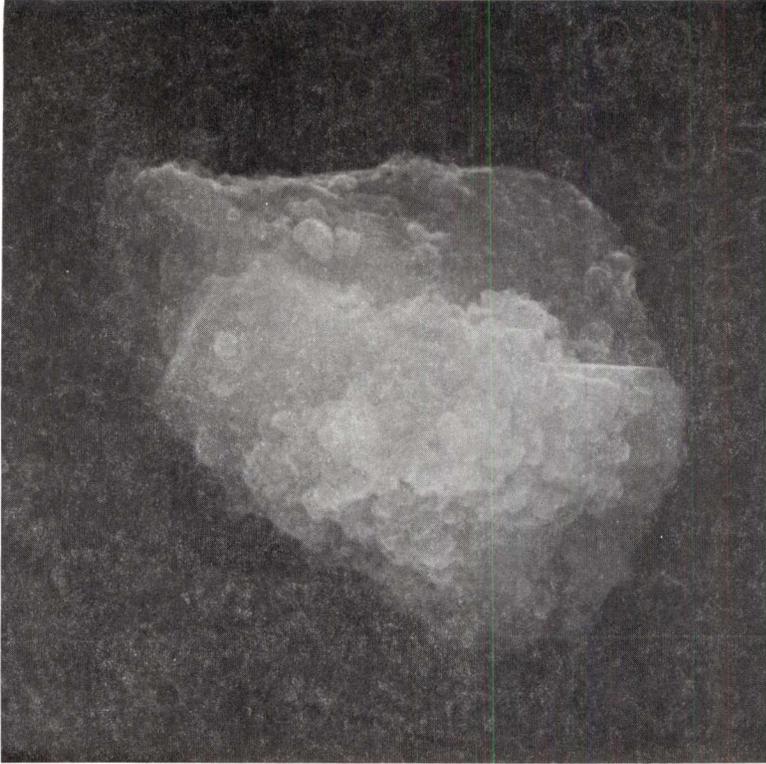


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
6	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black		D
<u>TYPE</u>	<u>COMMENTS</u>	
C	Sample of W7010*A	

S-85-35022

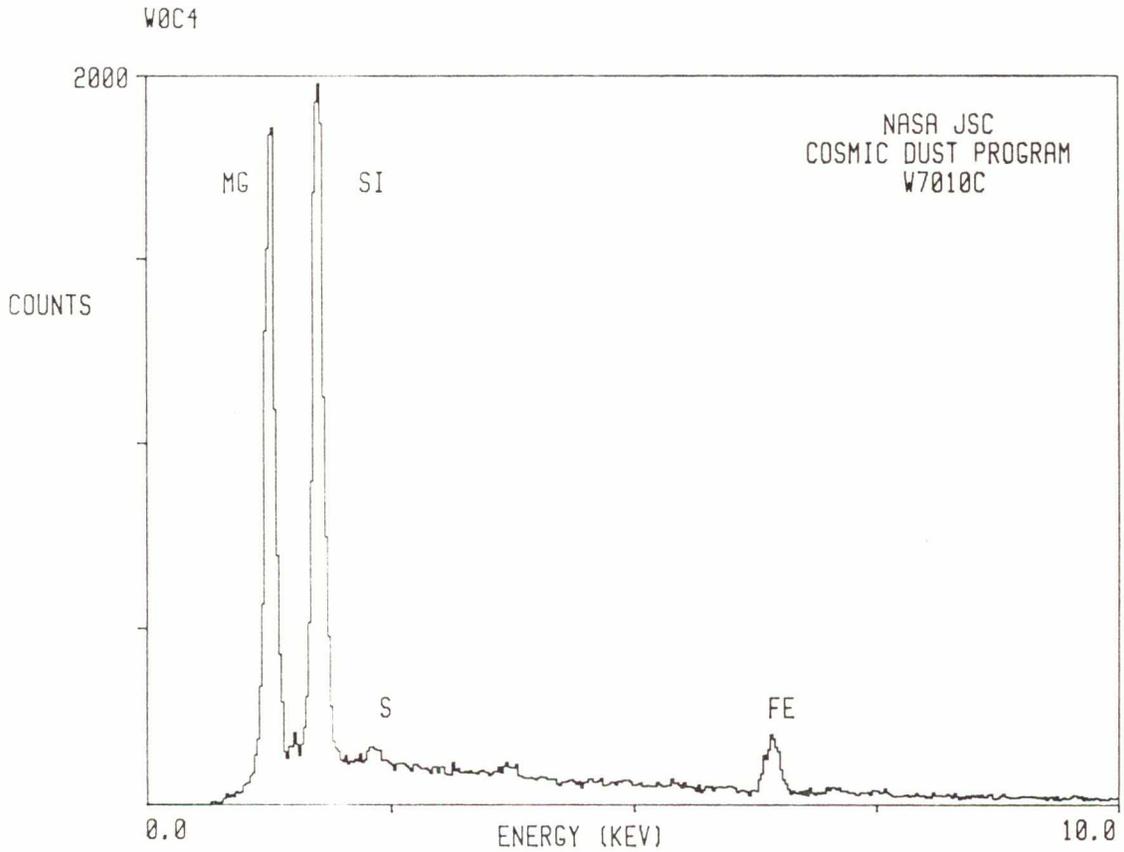


W7010C4



<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
8x5	I	O
<u>COLOR</u>		<u>LUSTER</u>
Brown to Black		SM/D
<u>TYPE</u>	<u>COMMENTS</u>	
C	Sample of W7010*A	

S-85-35025



W7028D1



SIZE SHAPE TRANS.

10x12 I O

COLOR LUSTER

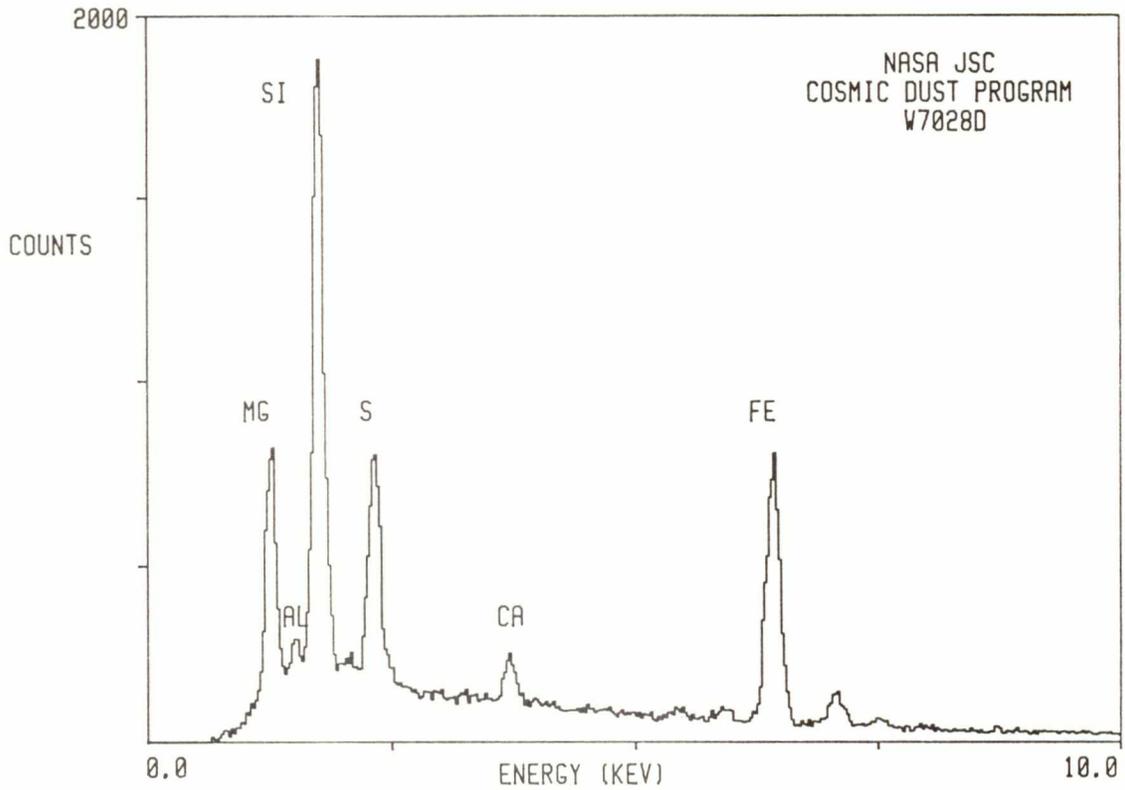
Yellow, Brown SV/D
and Black

TYPE COMMENTS

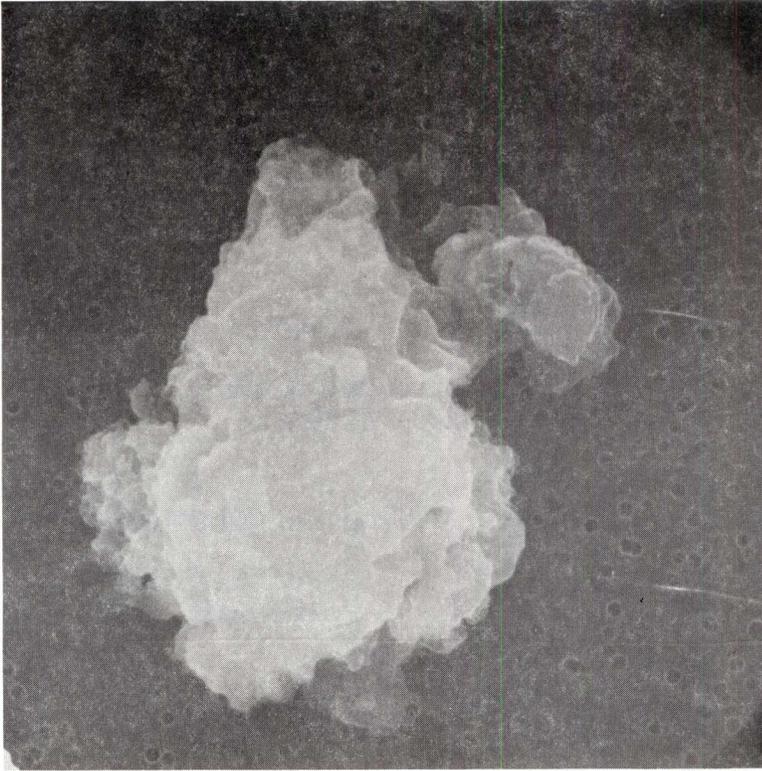
C Particle from
Prime Area #III

S-85-36002

W801



W7029K 1

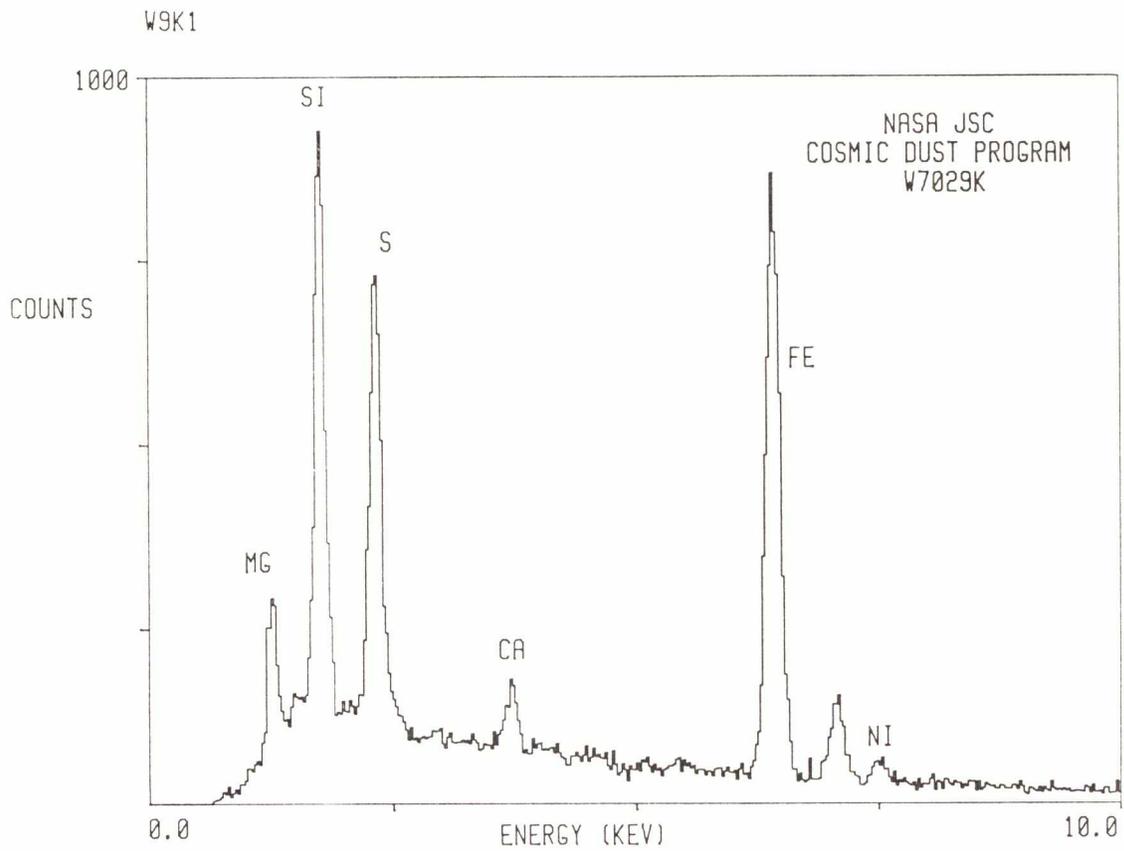


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
15	I	O/TL

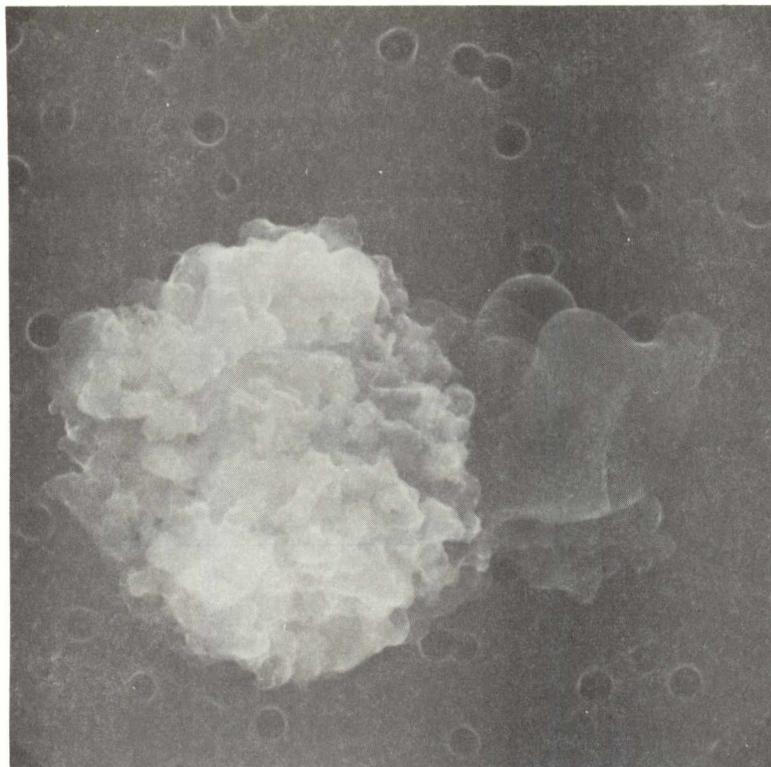
<u>COLOR</u>	<u>LUSTER</u>
Yellow, Brown and Black	SV/D

<u>TYPE</u>	<u>COMMENTS</u>
C	Sample of W7029*A (Prime Area I)

S-85-35999



W7029K2



SIZE SHAPE TRANS.

10x7 I/S O/TL

COLOR LUSTER

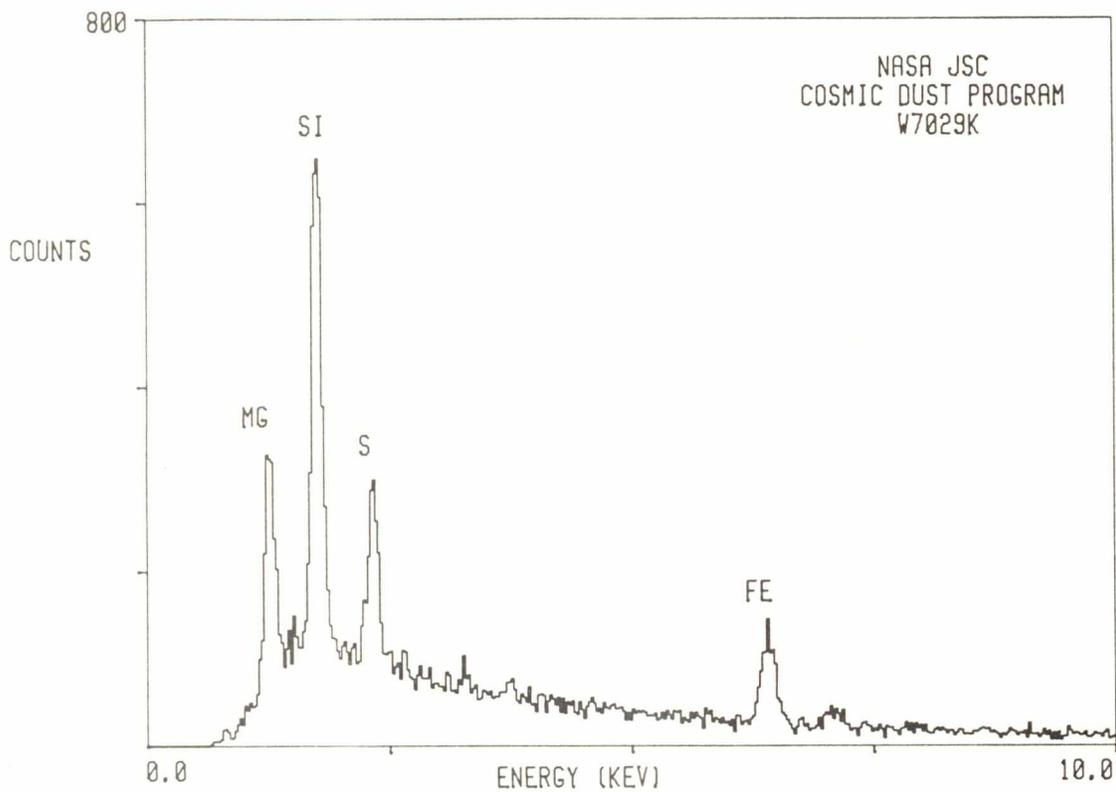
Black with
Yellow
Appendage SV/D

TYPE COMMENTS

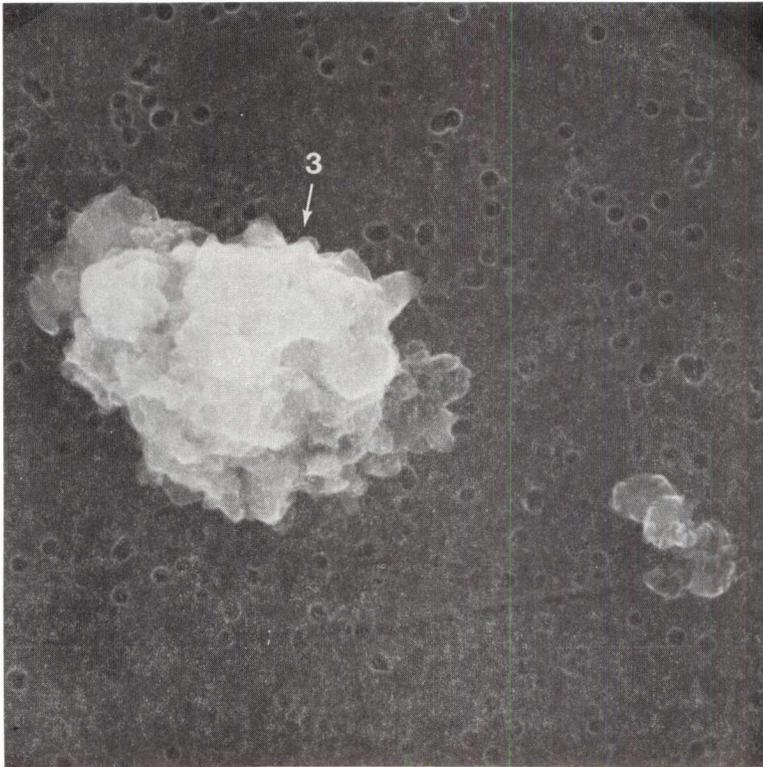
C Sample of W7029*B
(Prime Area II)

S-85-36000

W9K2A

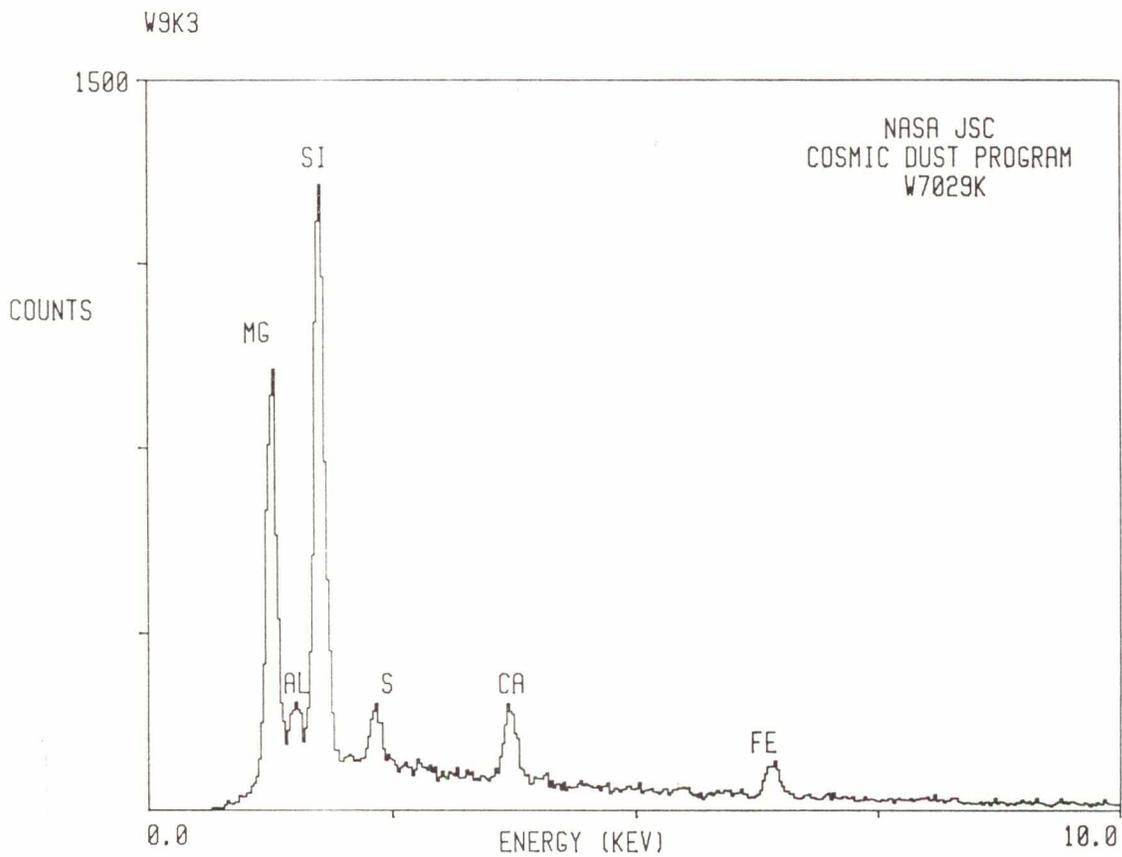


W7029K3

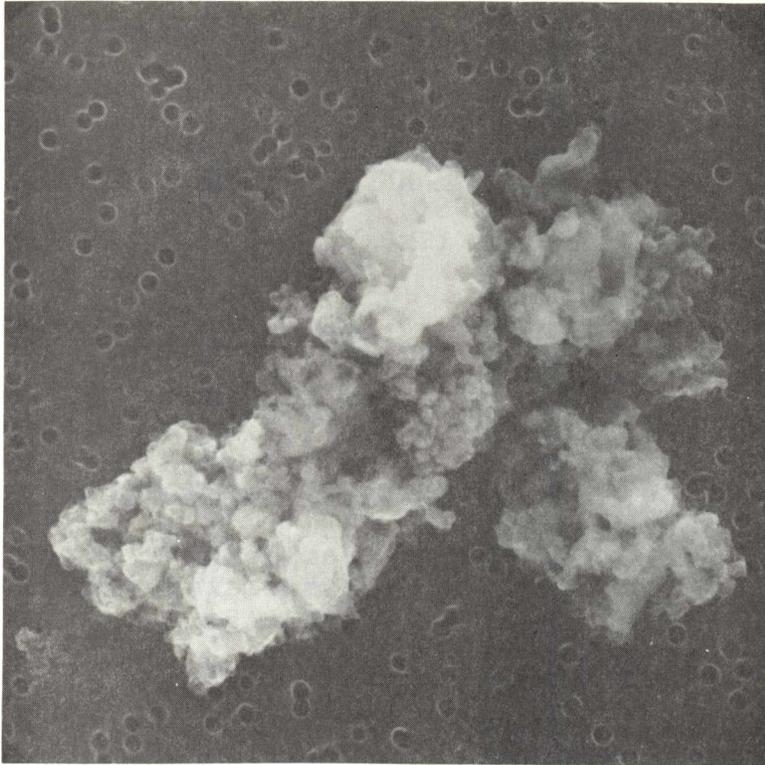


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
10x8	I	O/TL
<u>COLOR</u>		<u>LUSTER</u>
Brown to Colorless		SV/D
<u>TYPE</u>	<u>COMMENTS</u>	
C		

S-85-36001



W7031E1



SIZE SHAPE TRANS.

15x12 I O/TL

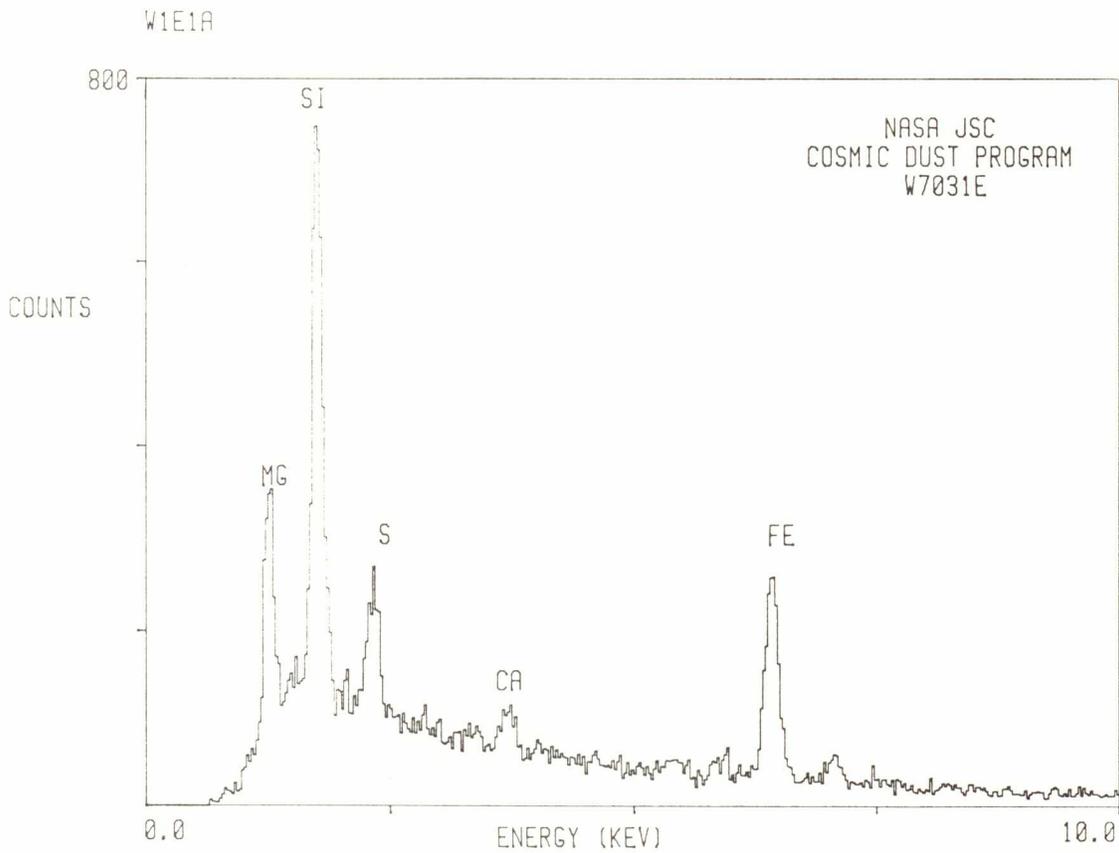
COLOR LUSTER

Yellow to Black SV/D

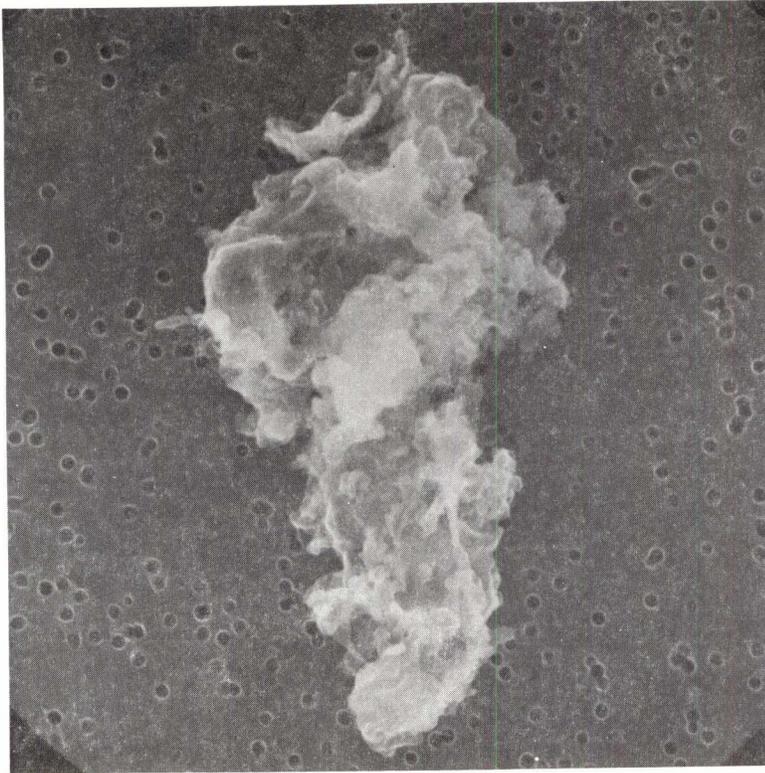
TYPE COMMENTS

C Sample of W7031*A;
associated with
W7031A1

S-85-35993



W7031E2

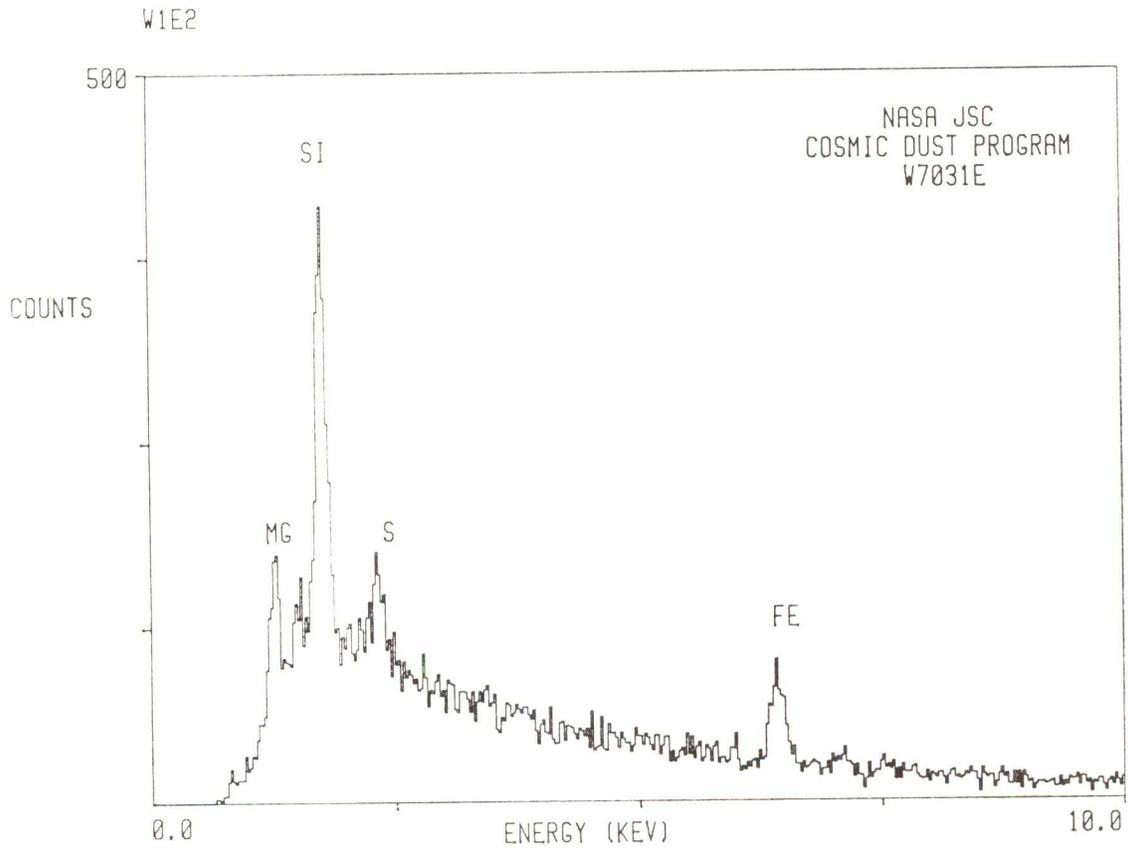


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
17x8	I	O

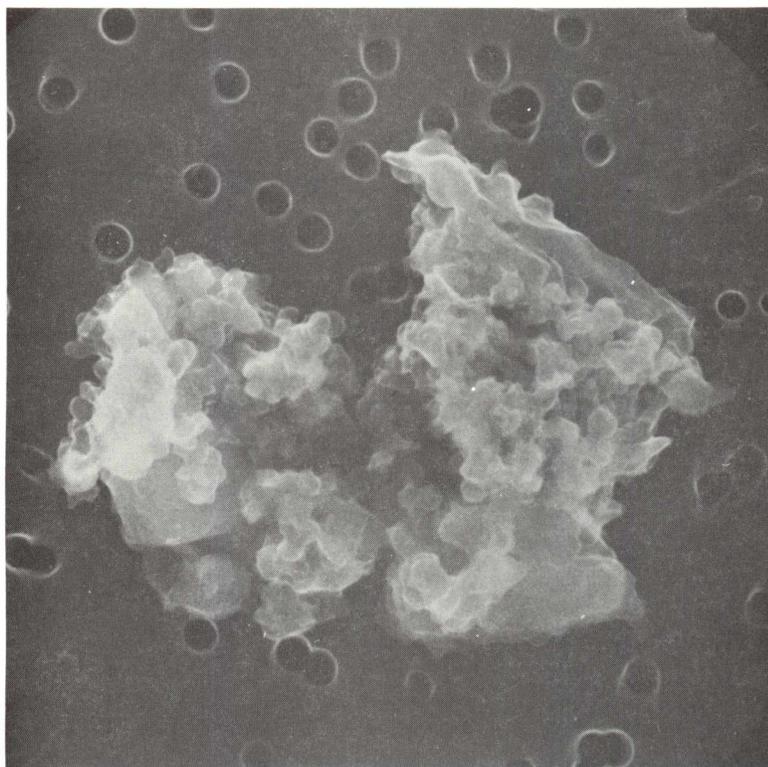
<u>COLOR</u>	<u>LUSTER</u>
Yellow to Black	M/D

<u>TYPE</u>	<u>COMMENTS</u>
C	Sample of W7031*C; associated with W7031A5

S-85-35994



W7031E3



SIZE SHAPE TRANS.

7x5 I O

_____ COLOR _____ LUSTER

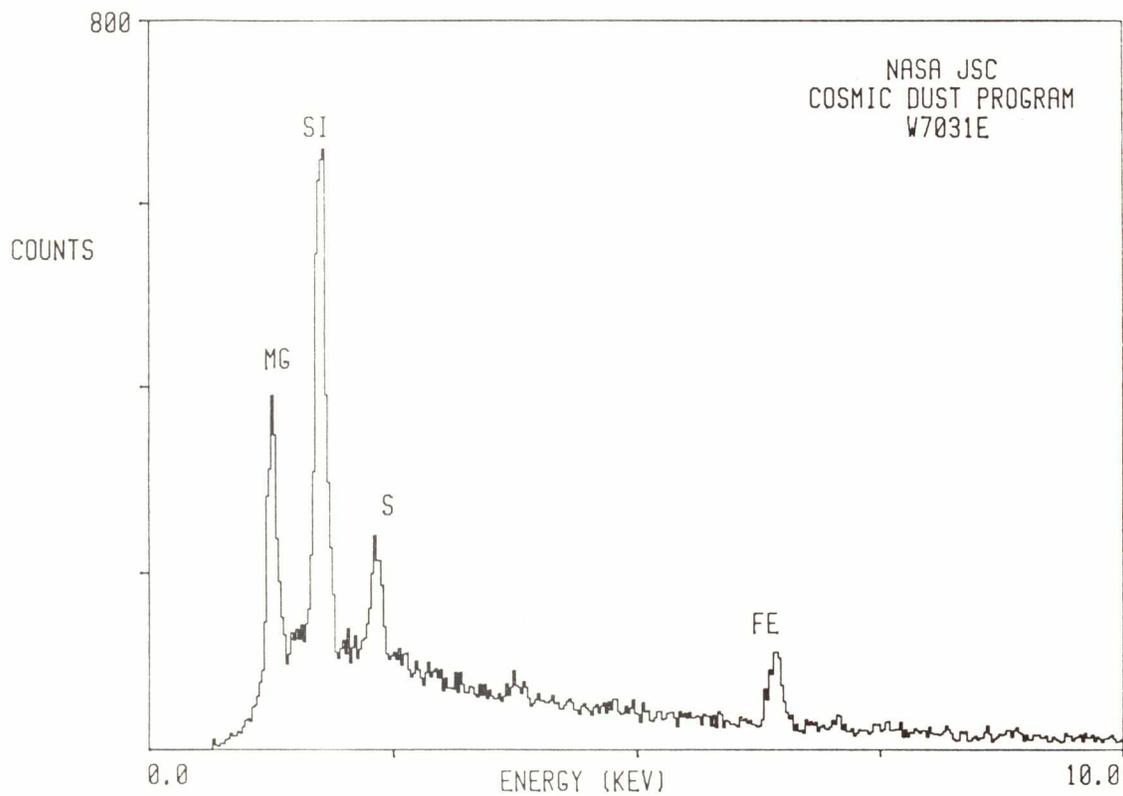
Yellow to Black SV/D

TYPE COMMENTS

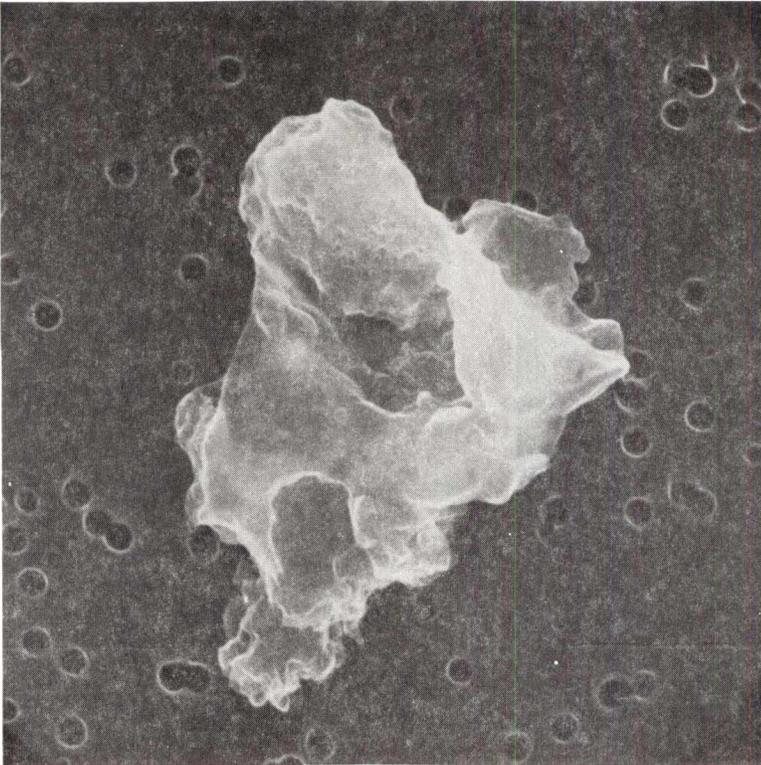
C Sample of W7031*B;
associated with
W7031A2 and
W7031E4

S-85-35995

W1E3A



W7031E4

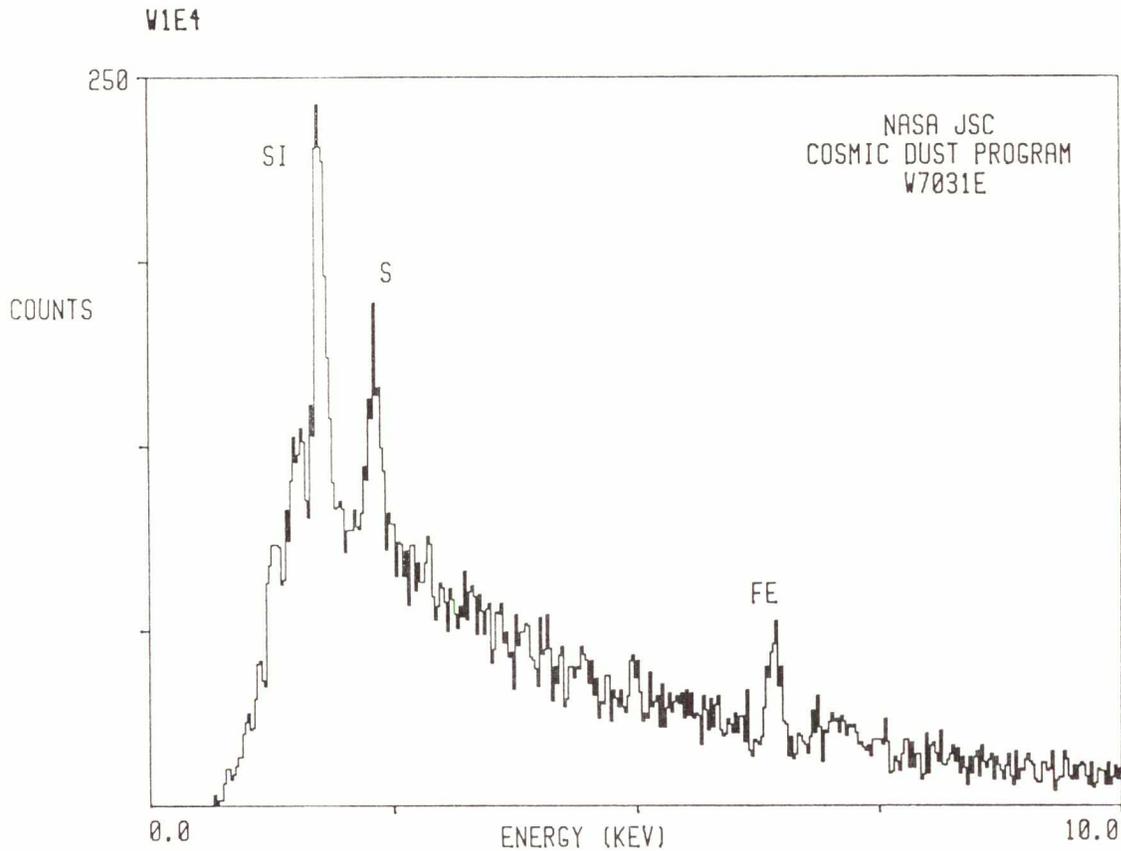


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
7	I	O

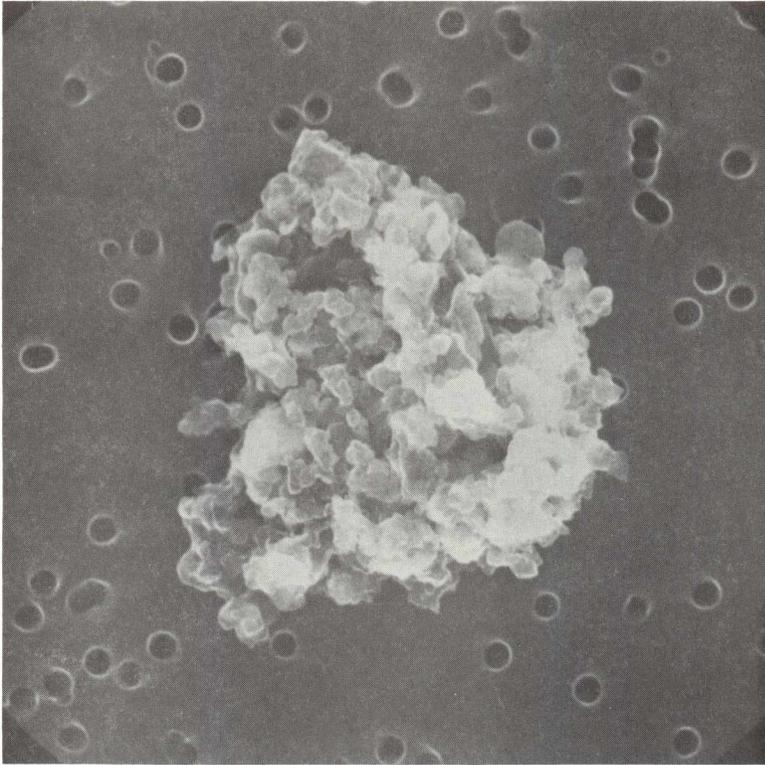
<u>COLOR</u>	<u>LUSTER</u>
Yellow to Black	SV/D

<u>TYPE</u>	<u>COMMENTS</u>
C	Sample of W7031*B; associated with W7031A2 and W7031E3

S-85-35996



W7066B1



SIZE SHAPE TRANS.

7 I O

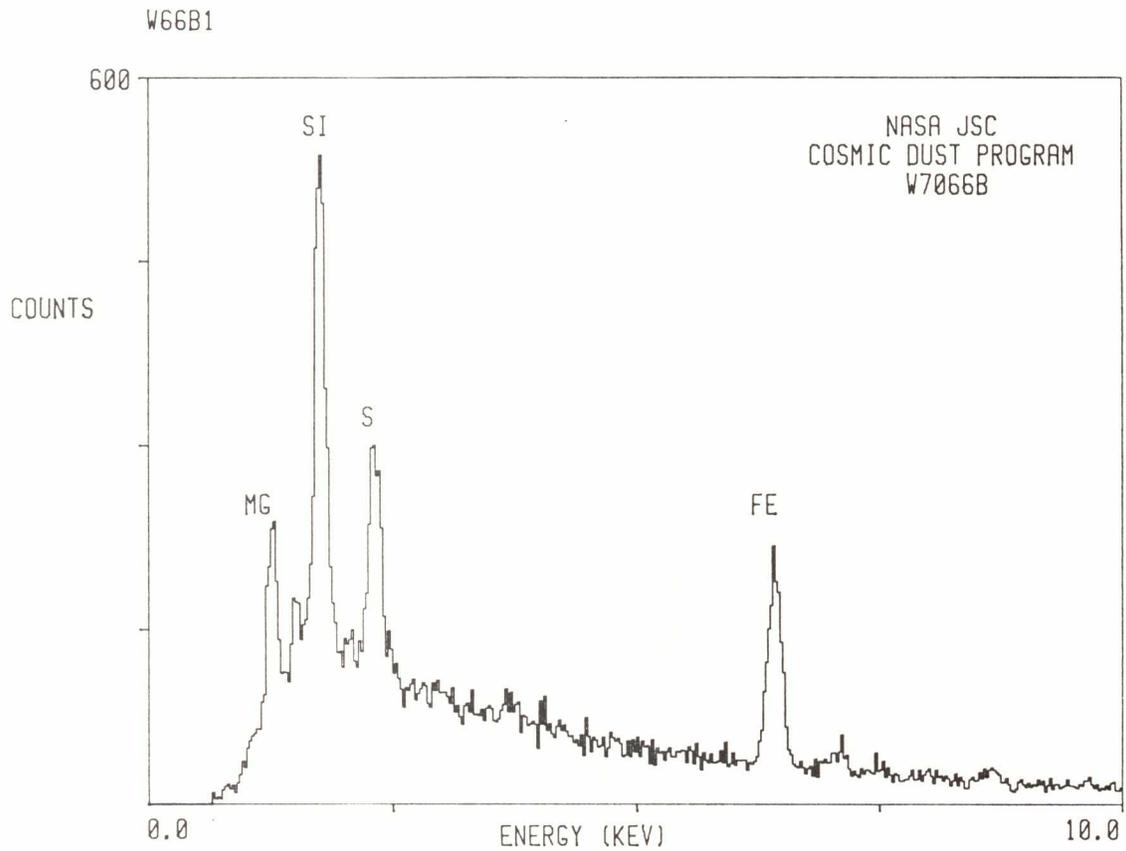
COLOR LUSTER

Black SV/D

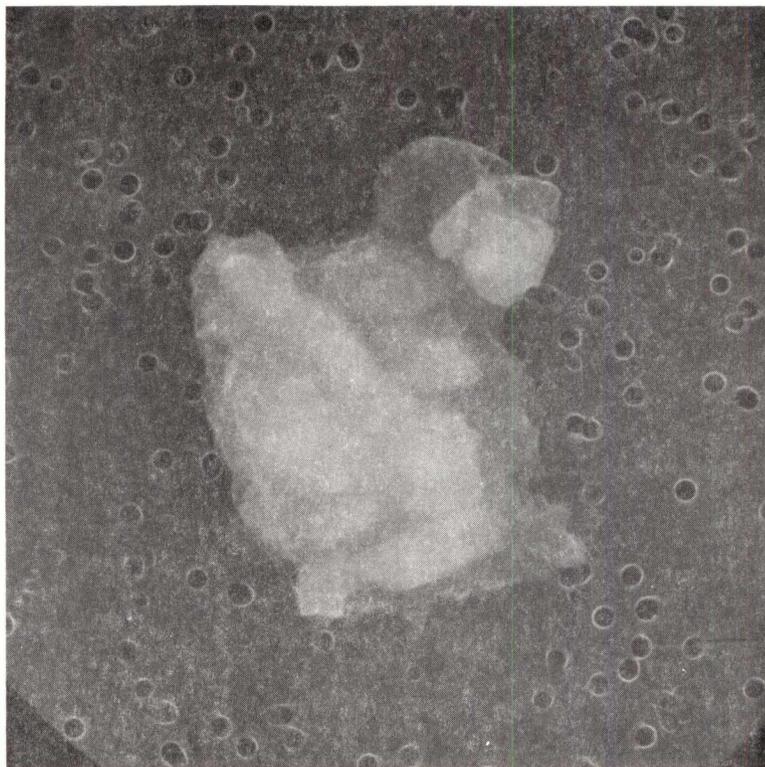
TYPE COMMENTS

C Sample of W7066*A;
associated with
W7066A1 and A5

S-85-36026

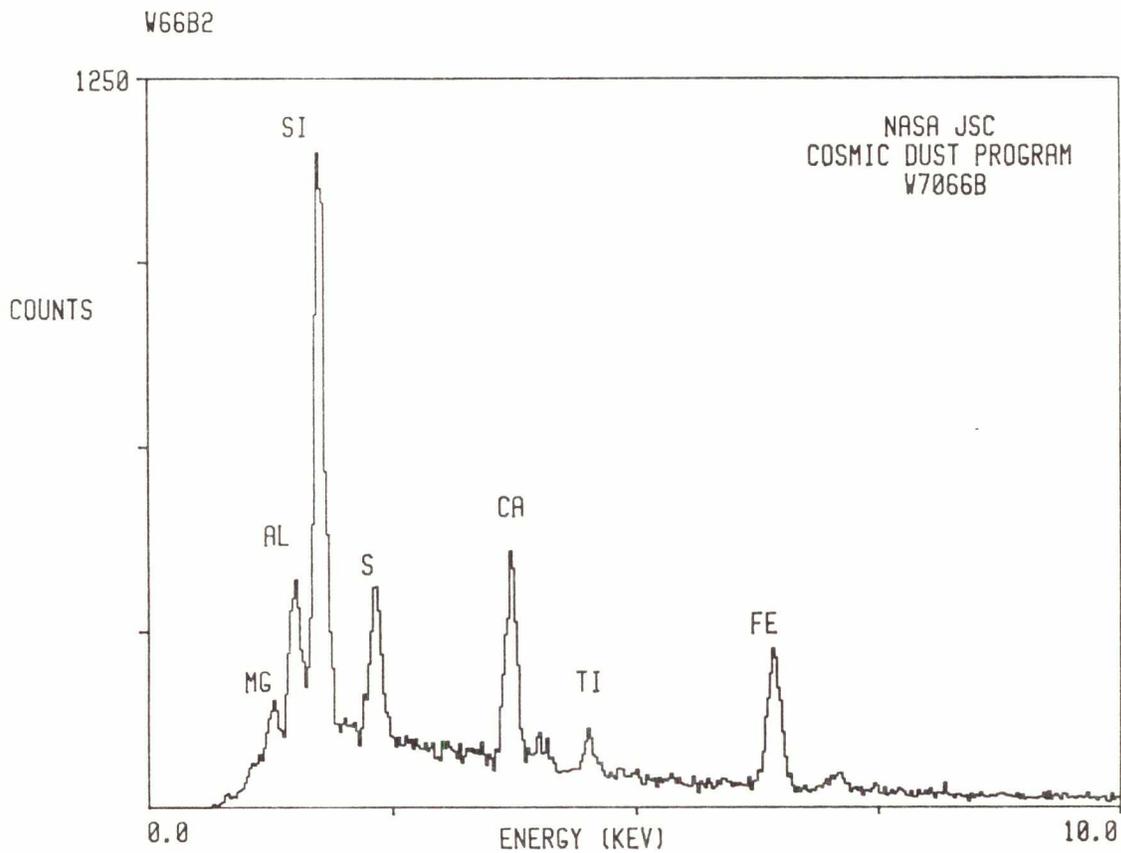


W7066B2

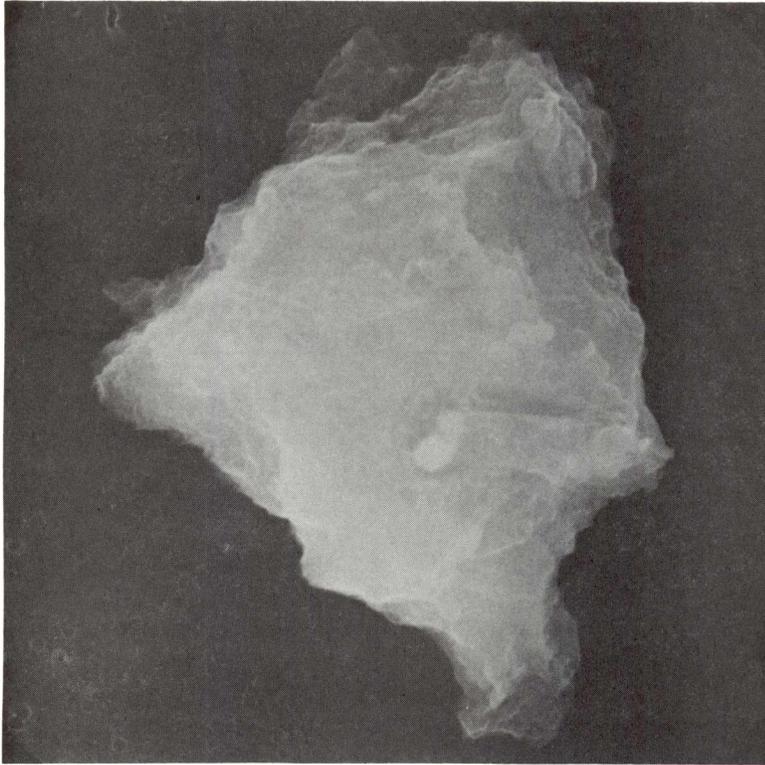


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
10	I	O
<u>COLOR</u>		<u>LUSTER</u>
Gold to Brown		SM/M
<u>TYPE</u>	<u>COMMENTS</u>	
C		

S-85-36027



W7069B1



SIZE SHAPE TRANS.

18 I O

_____ COLOR _____ LUSTER

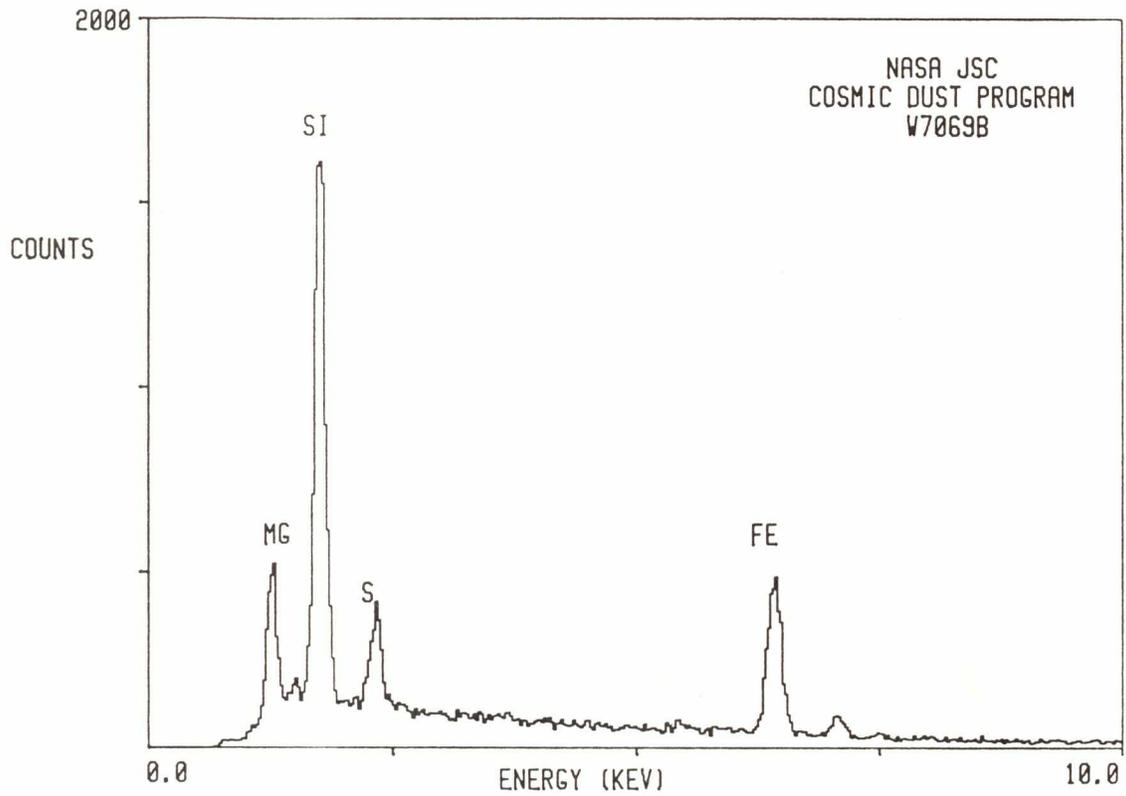
Black to Bronze SV/D

TYPE COMMENTS

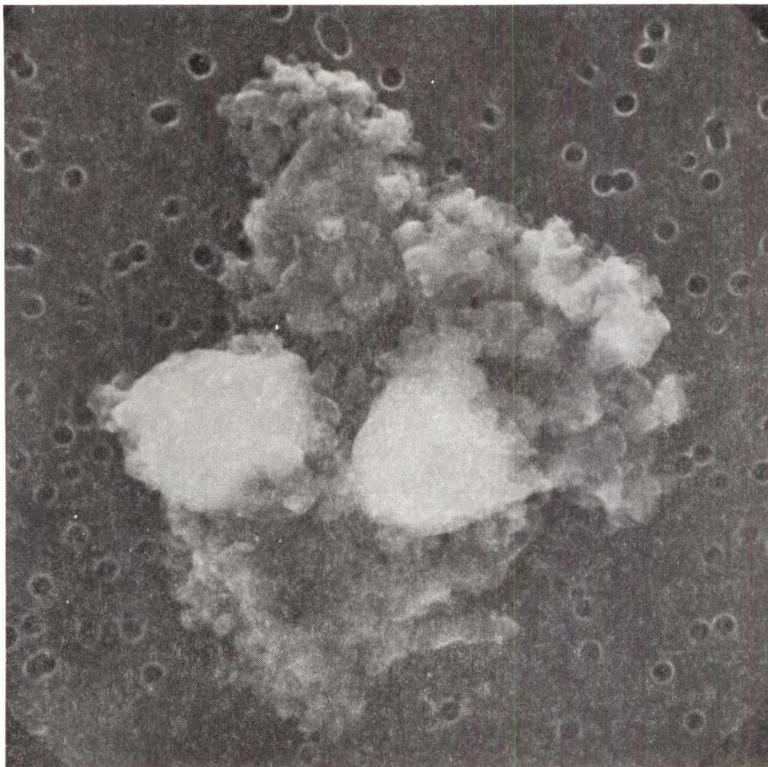
C Sample of W7069*B;
 associated with
 W7069A2

S-85-36053

W9B1



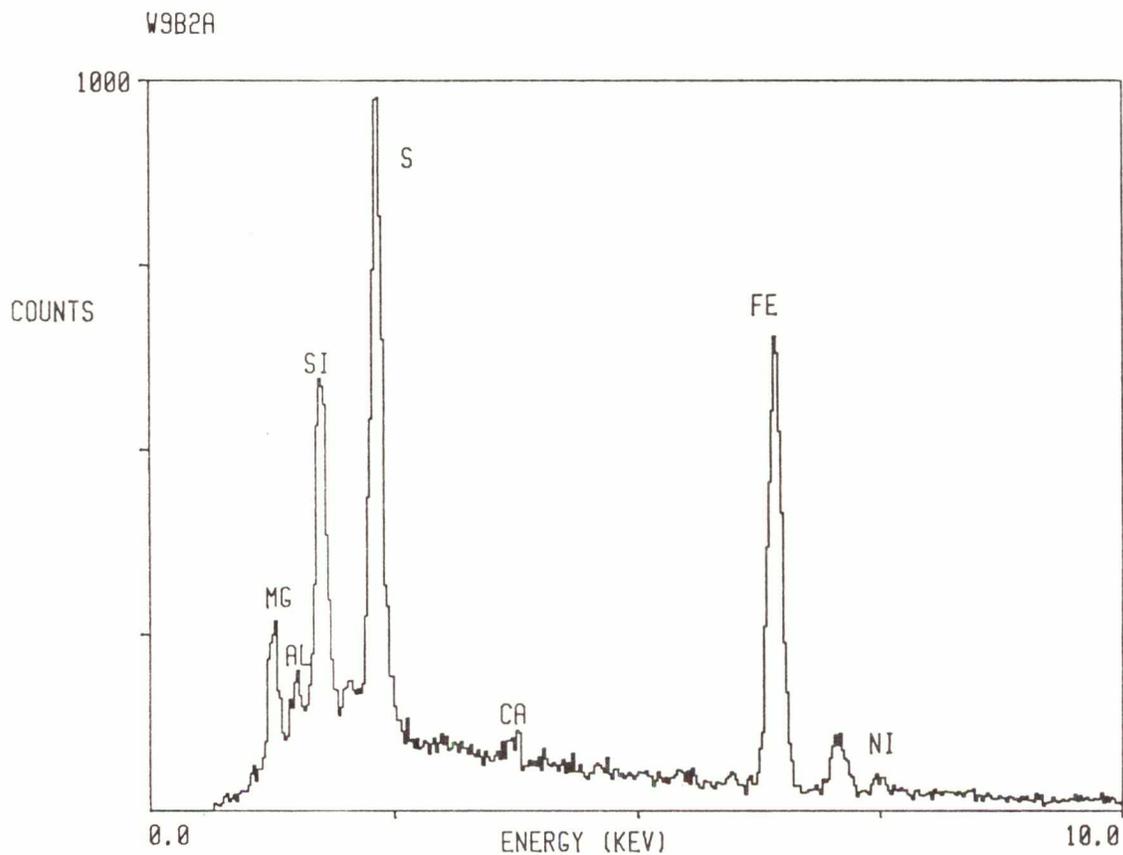
W7069B2



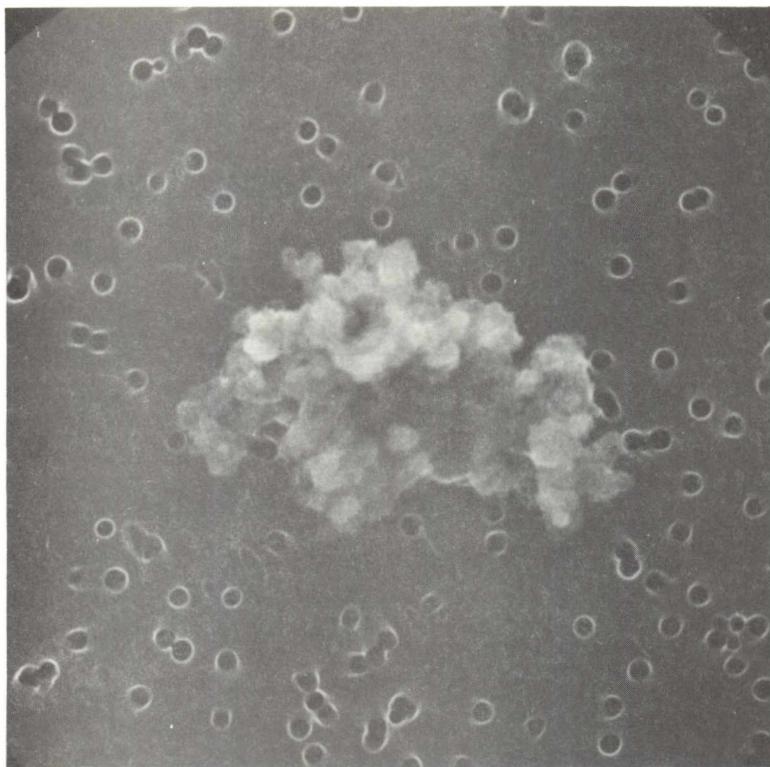
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
13	I	O
<u>COLOR</u>		<u>LUSTER</u>
Green to Black		SM/D
<u>TYPE</u>	<u>COMMENTS</u>	

C Sample of W7069*A;
associated with
W7069A1 and B3

S-85-36054



W7069B3



SIZE SHAPE TRANS.

7 I O

COLOR LUSTER

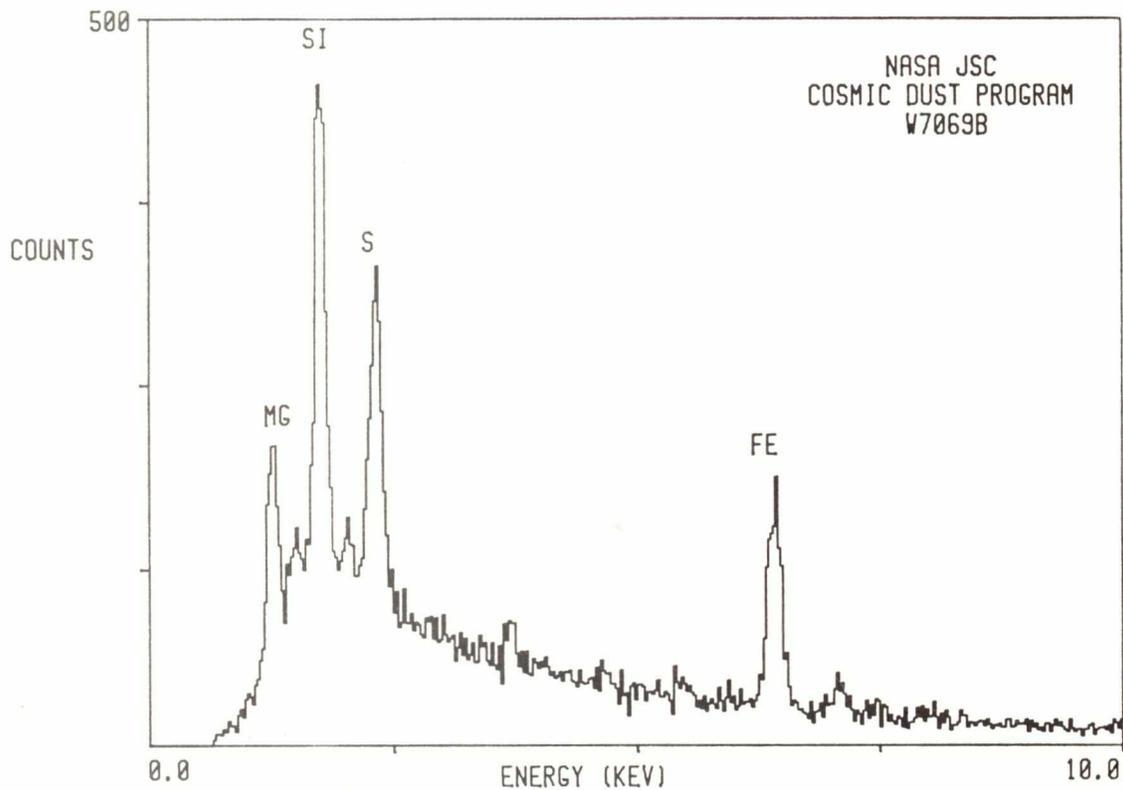
Green to Black SM/D

TYPE COMMENTS

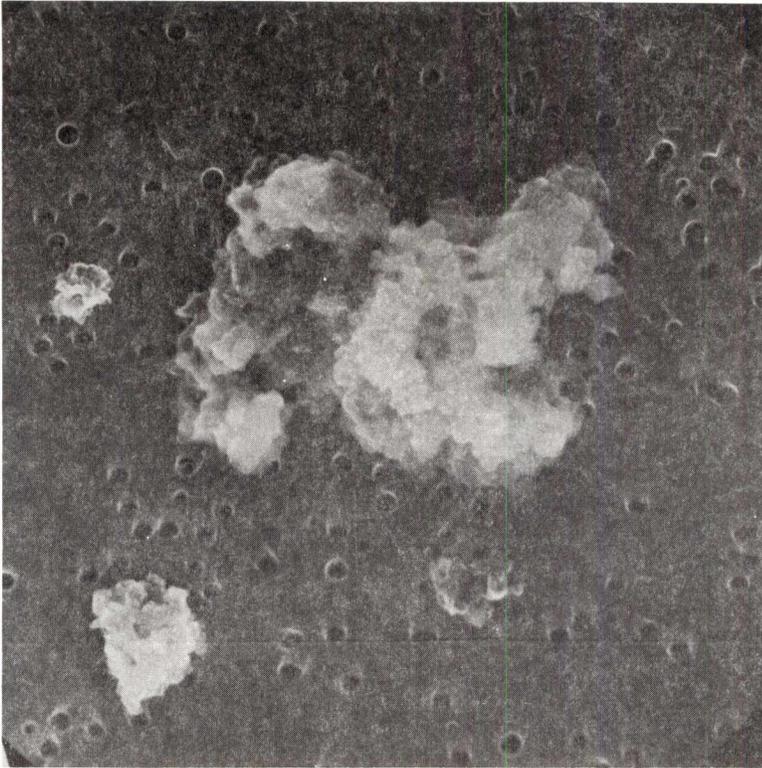
C Sample of W7069*A;
associated with
W7069A1 and B2

S-85-36055

W9B3



U2011C1



SIZE SHAPE TRANS.

9 I O

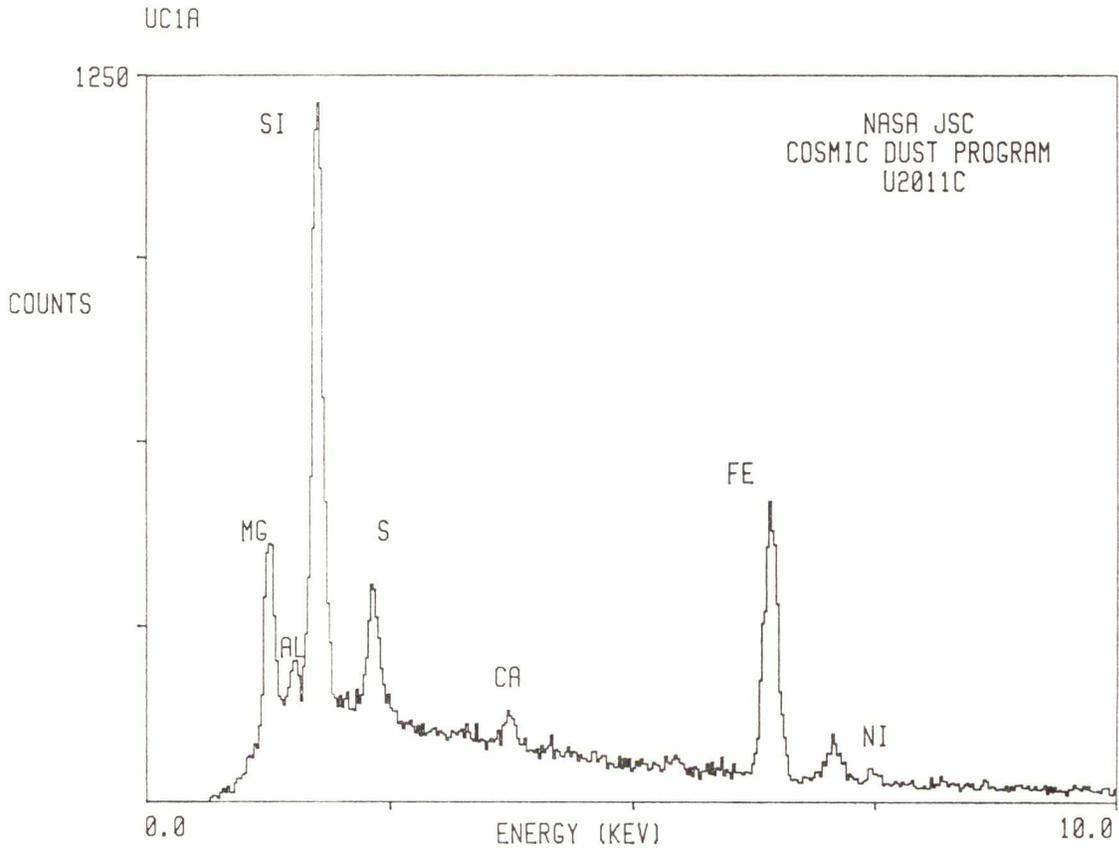
COLOR LUSTER

Yellow to Black D/SV

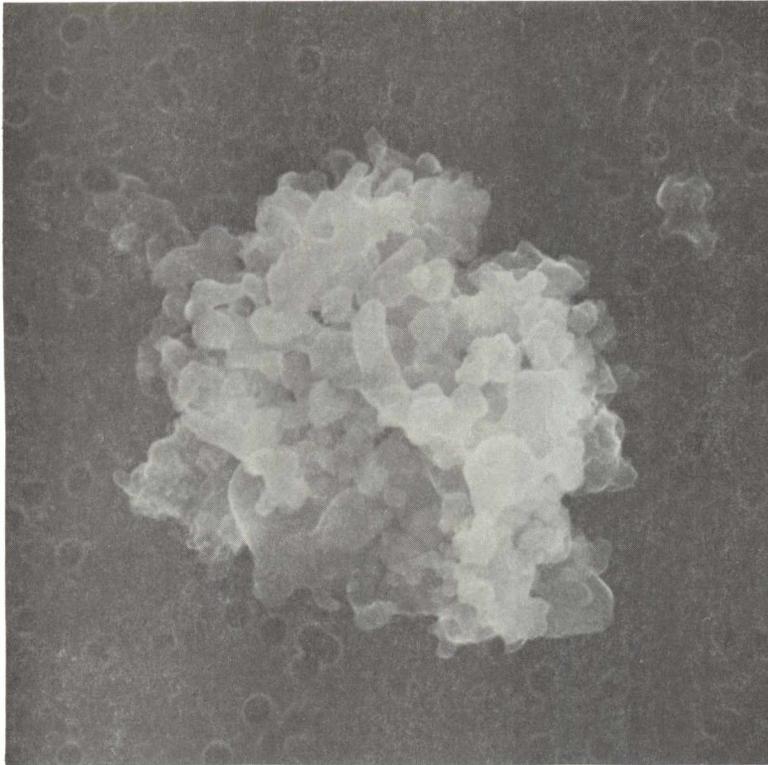
TYPE COMMENTS

C Sample of U2011*A;
associated with
U2011A2 and A4

S-85-36030



U2011C2

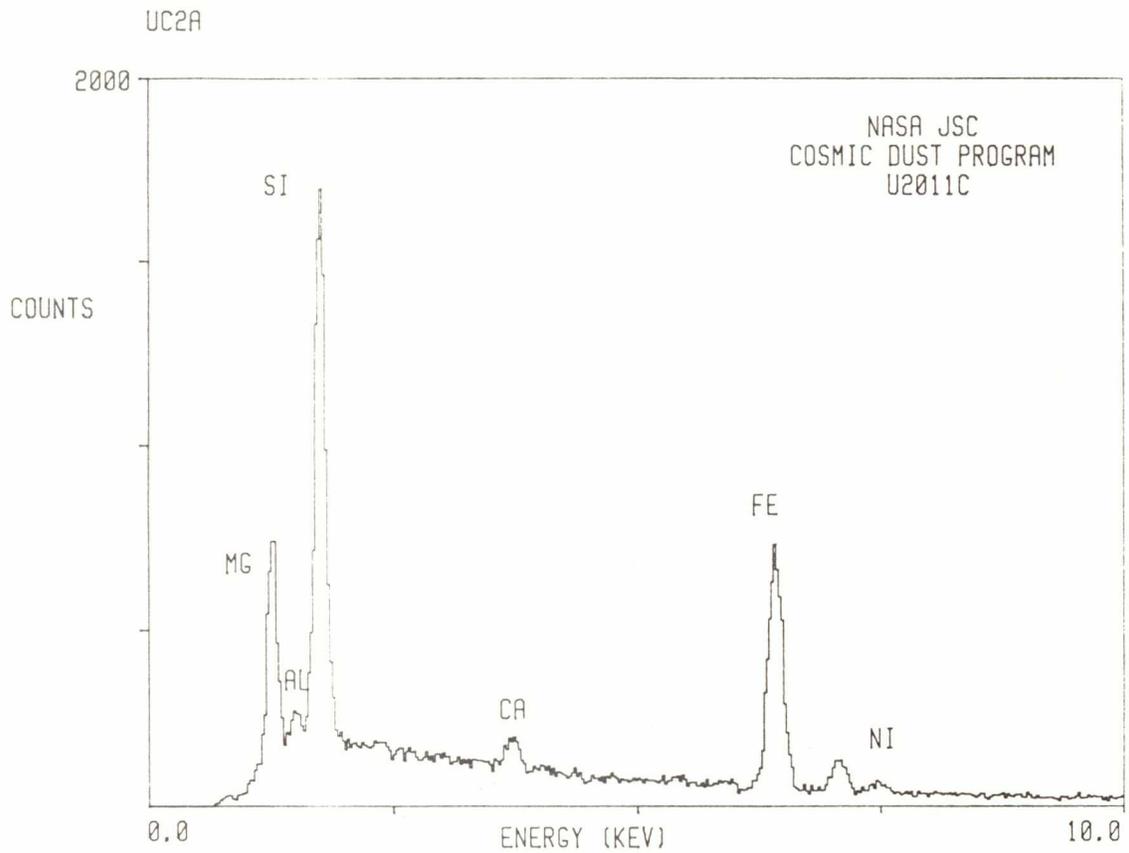


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
9	I	O

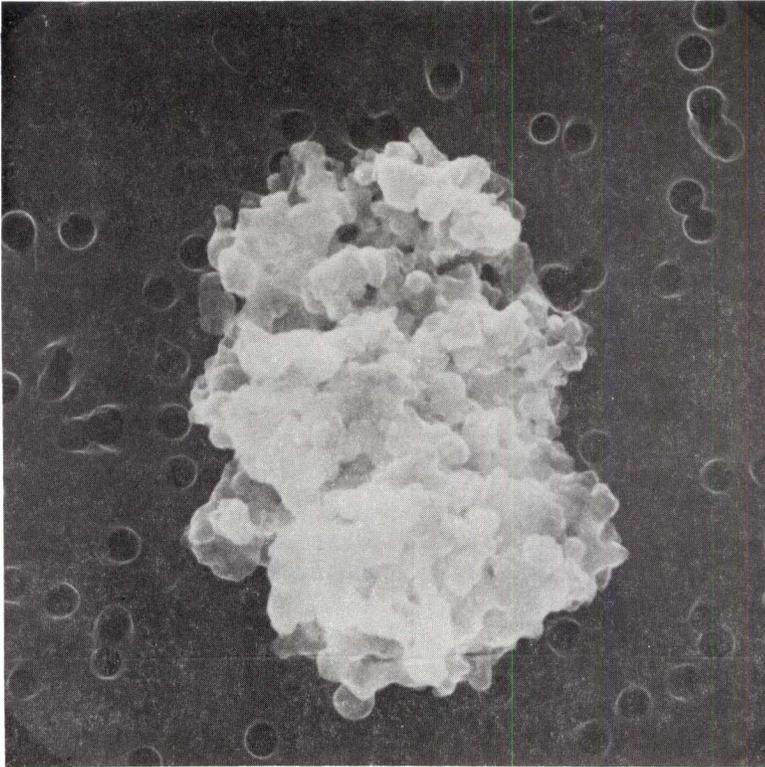
<u>COLOR</u>	<u>LUSTER</u>
Bronze to Black	SM/D

<u>TYPE</u>	<u>COMMENTS</u>
C	Sample of U2011*B; associated with U2011A5, C3 and C4

S-85-36031

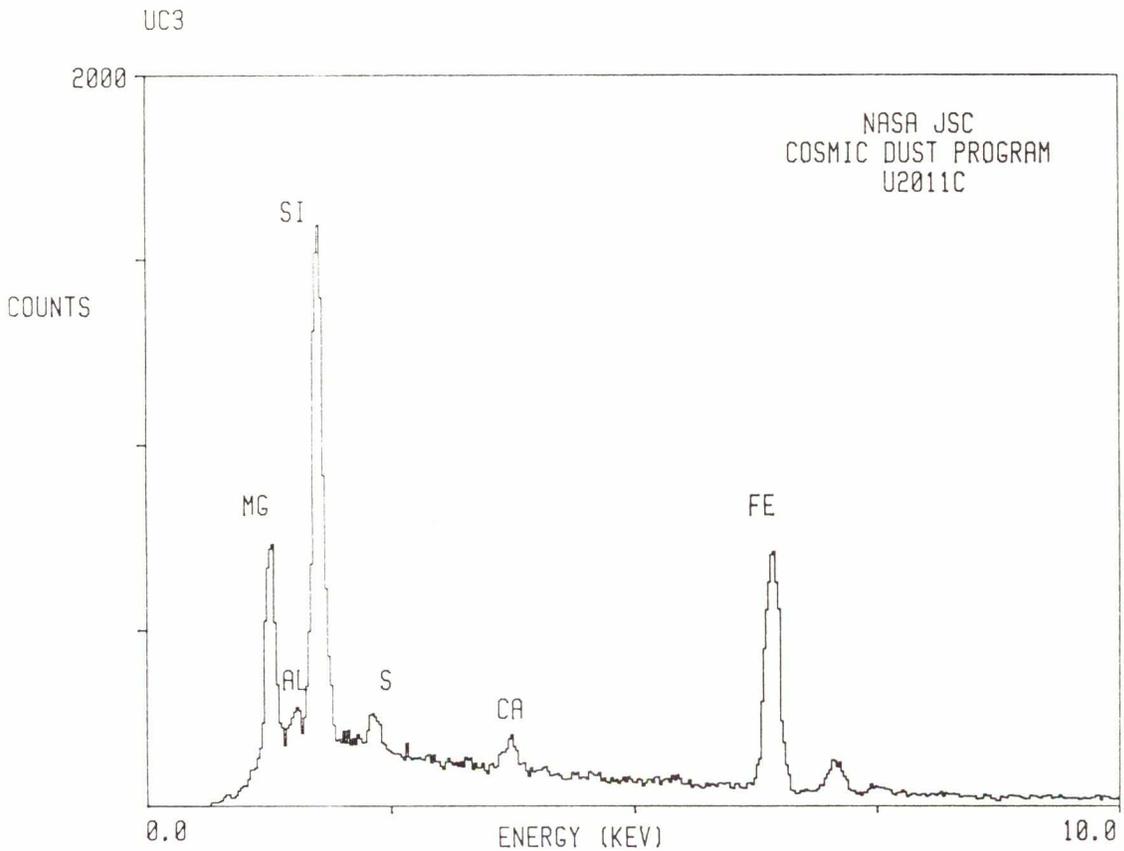


U2011C3

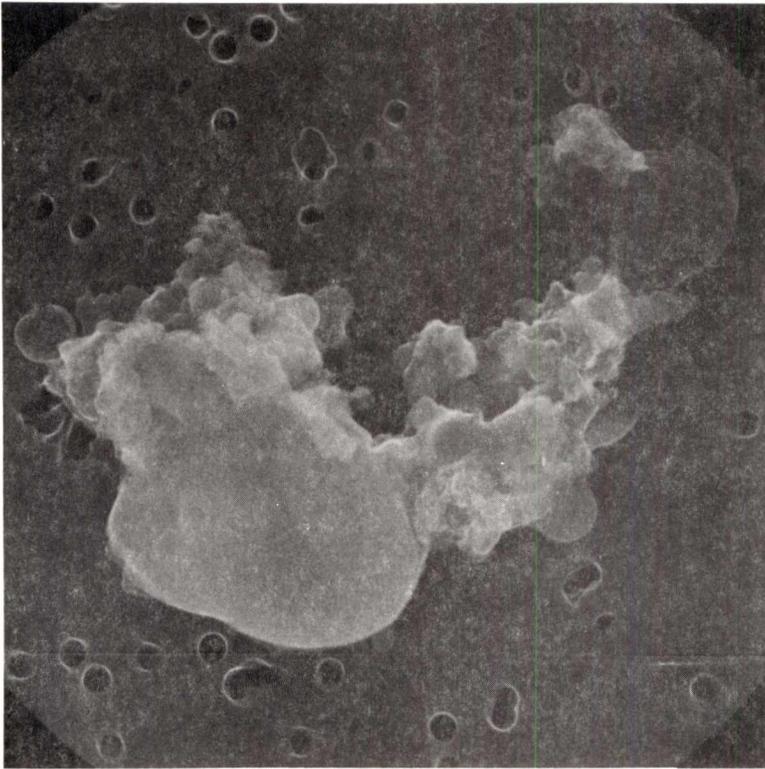


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
6	I	O
<u>COLOR</u>		<u>LUSTER</u>
Bronze to Black		SM/D
<u>TYPE</u>	<u>COMMENTS</u>	
C	Sample of U2011*B; associated with U2011A5, C2 and C4	

S-85-36032

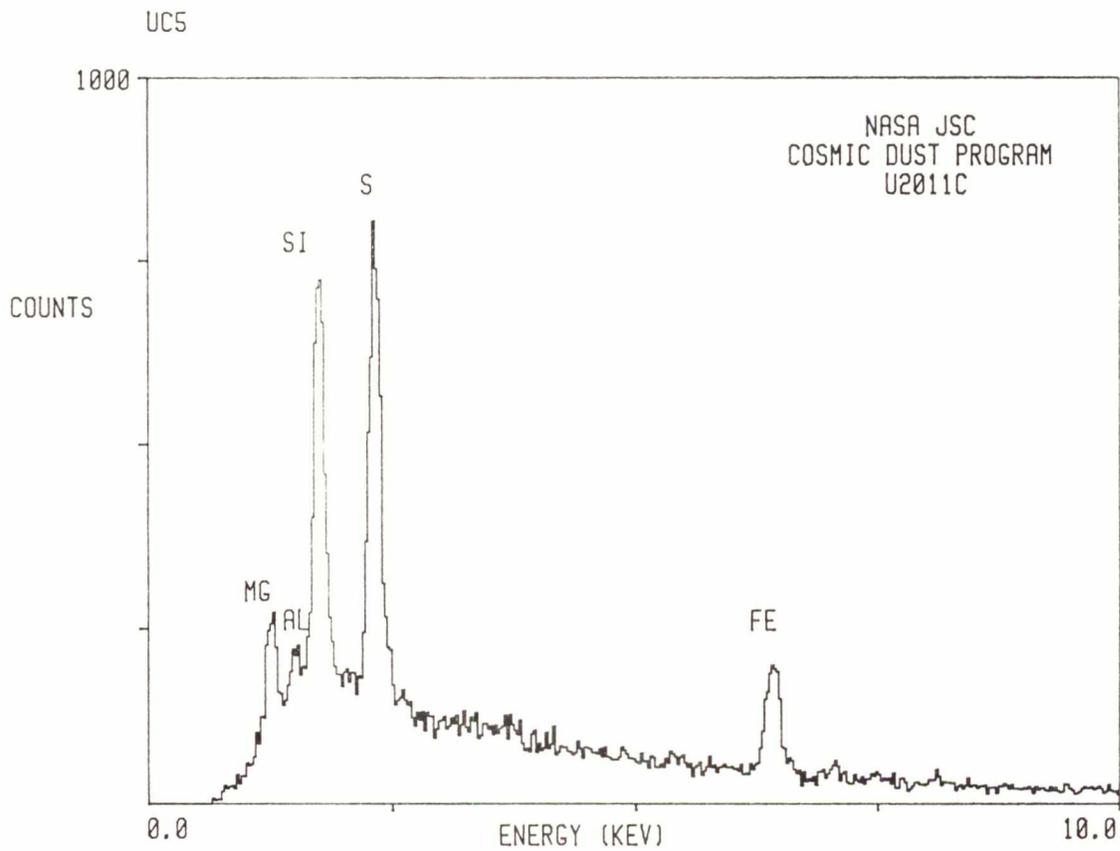


U2011C5

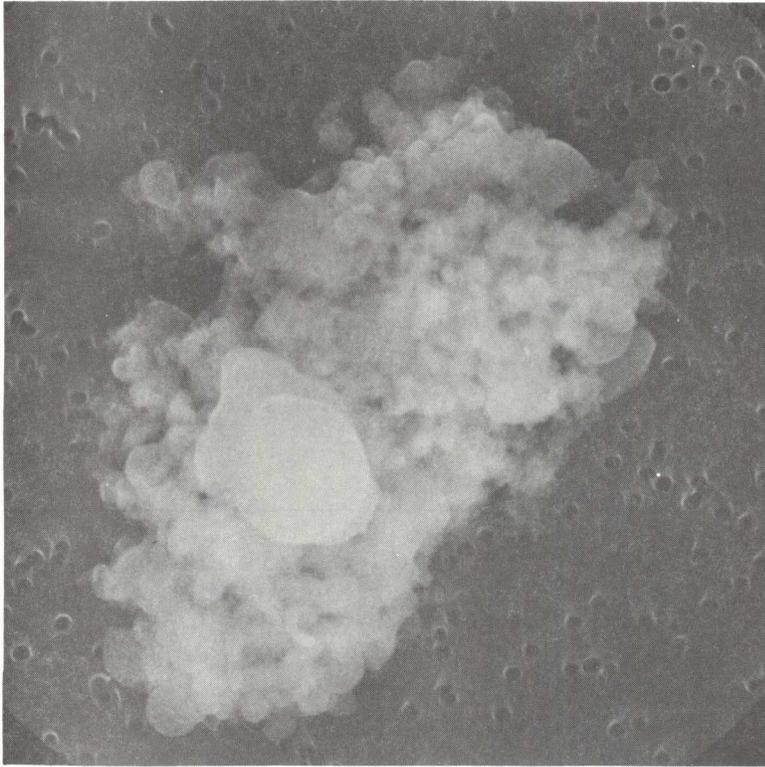


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
12x7	I	O/TL
<u>COLOR</u>		<u>LUSTER</u>
Lt. Brown to Black		SV/D
<u>TYPE</u>	<u>COMMENTS</u>	
C		

S-85-36034

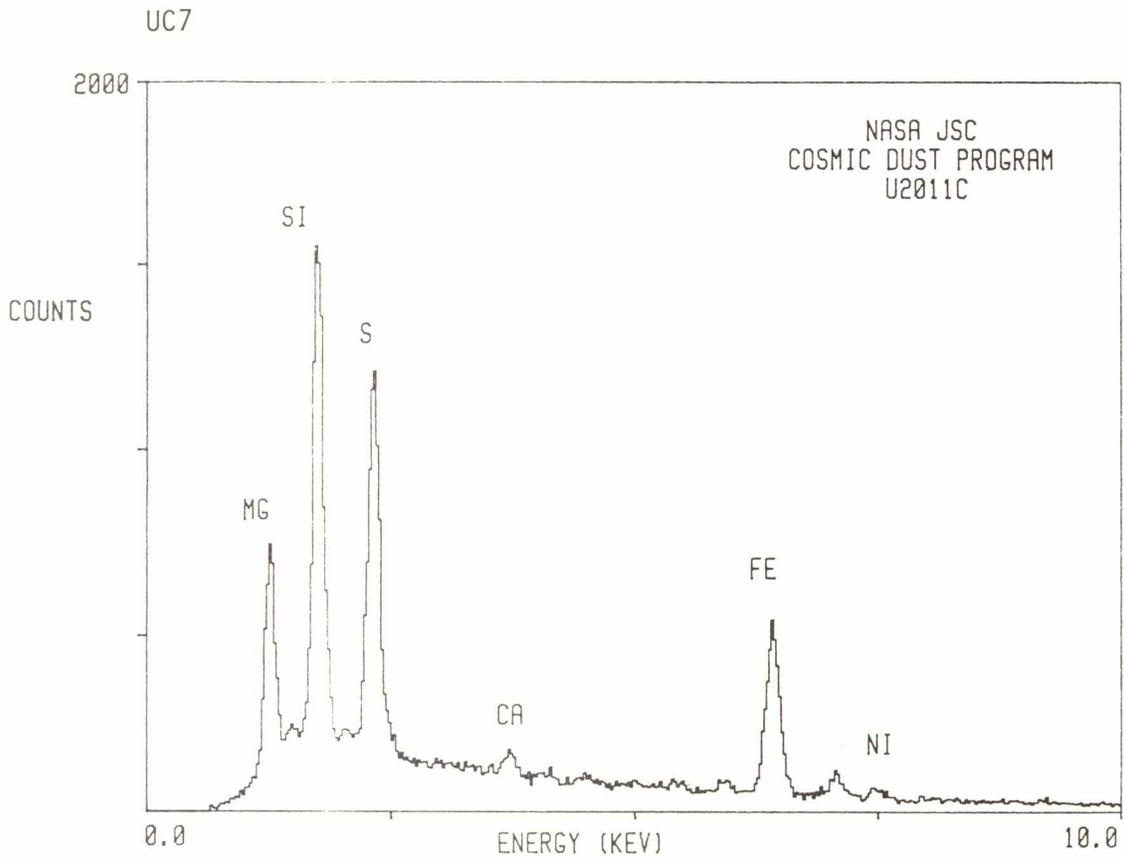


U2011C7

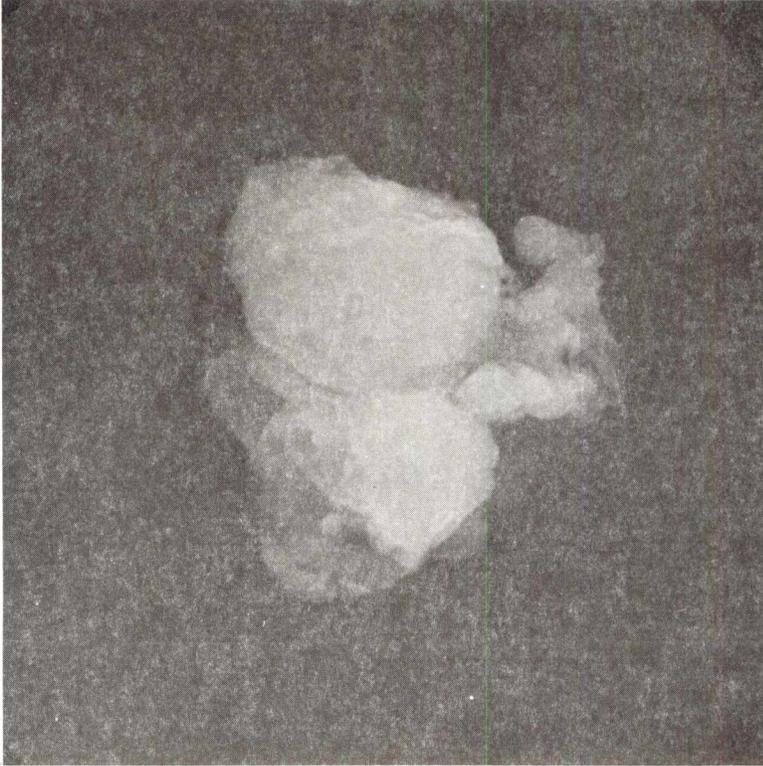


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
10x15	I	O
<u>COLOR</u>		<u>LUSTER</u>
Bronze to Black		SM/D
<u>TYPE</u>	<u>COMMENTS</u>	
C		

S-85-36036



U2015G1

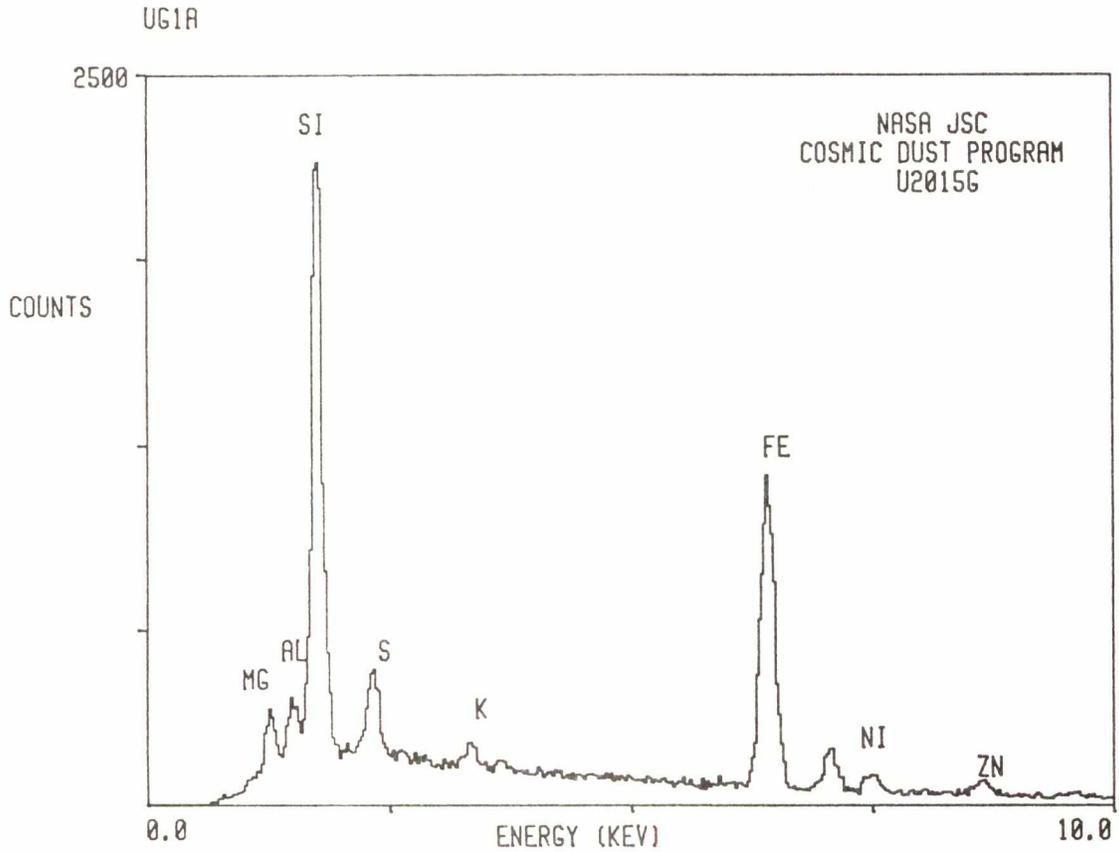


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
25	I	O/TL

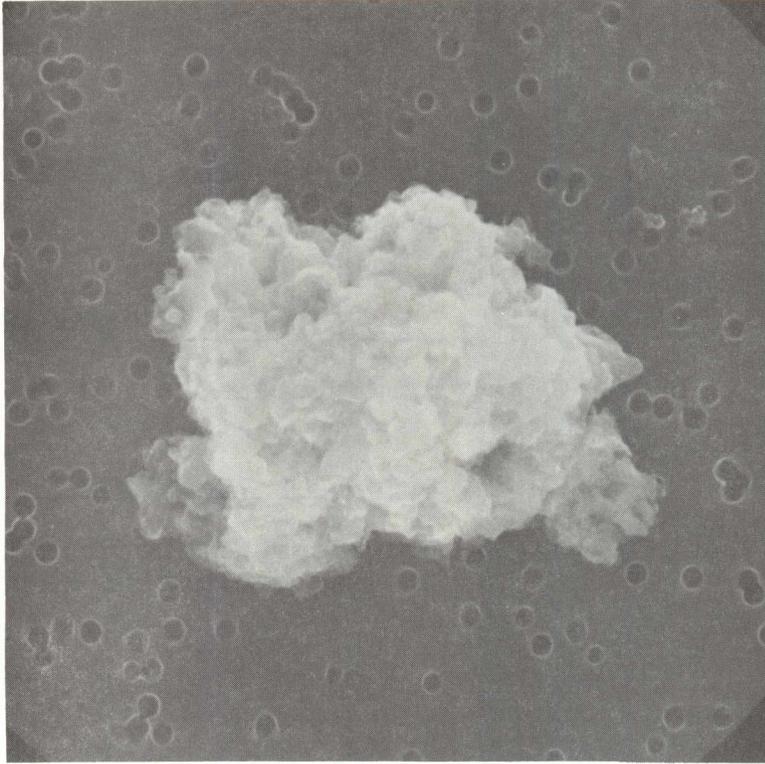
<u>COLOR</u>	<u>LUSTER</u>
Clear to Black	SM/D

<u>TYPE</u>	<u>COMMENTS</u>
C	Sample U2015*A; associated with U2015G2 and U2015B1-4,6

S-85-35992

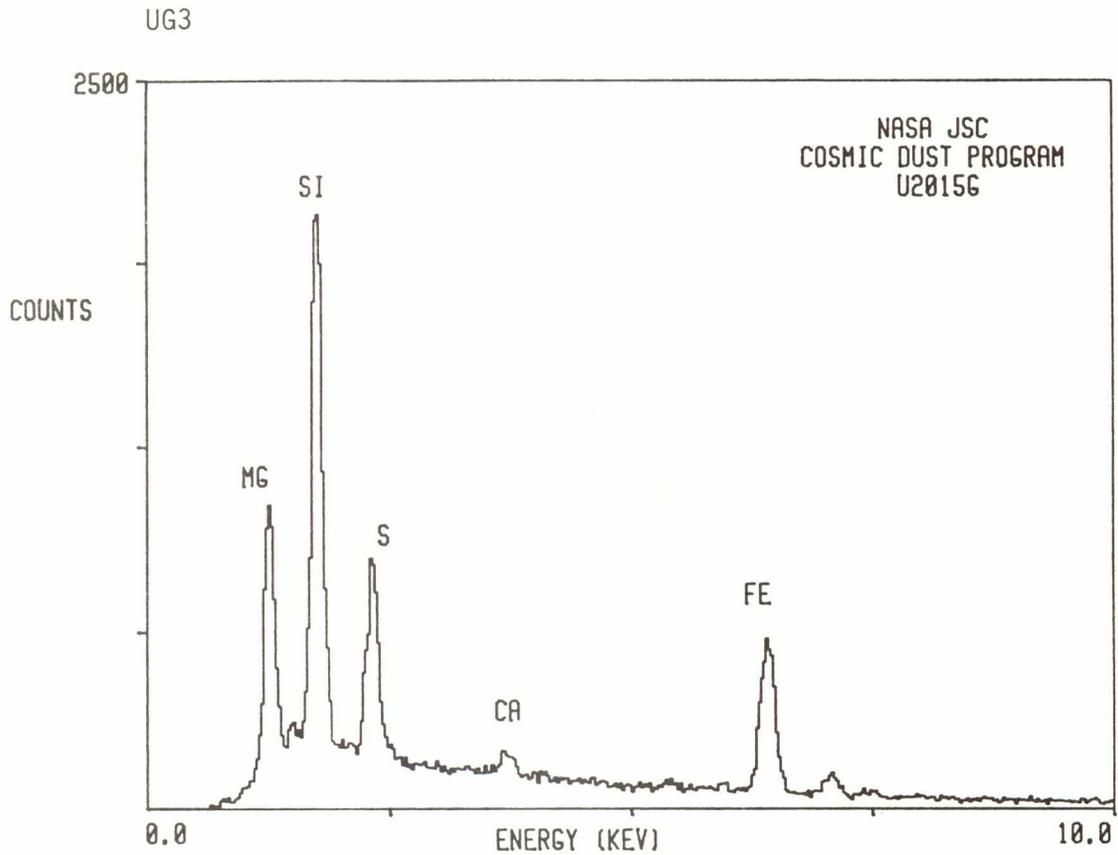


U2015G3

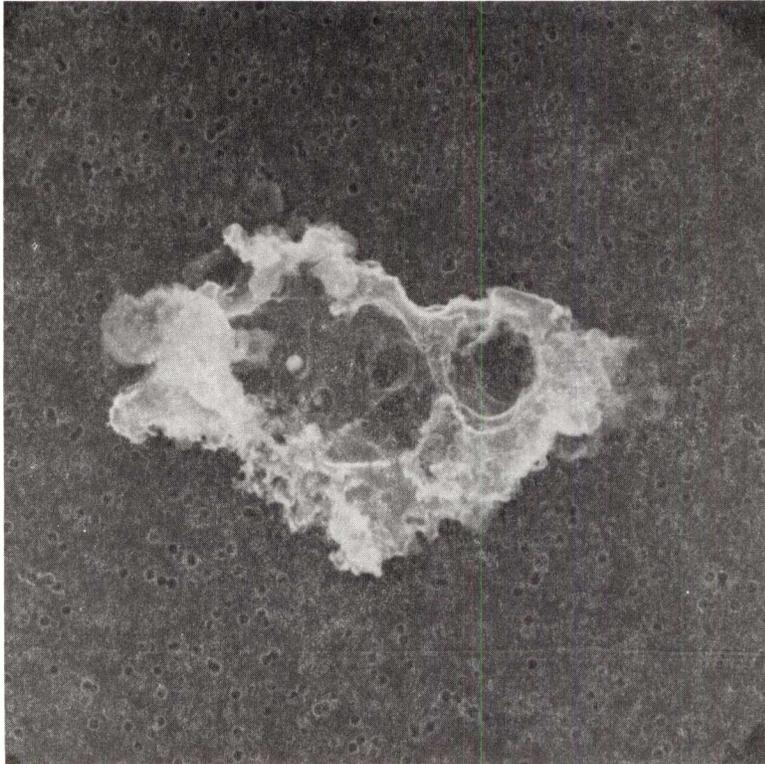


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
11	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black		D
<u>TYPE</u>	<u>COMMENTS</u>	
C	Sample of U2015*B; associated with U2015B9	

S-85-35990

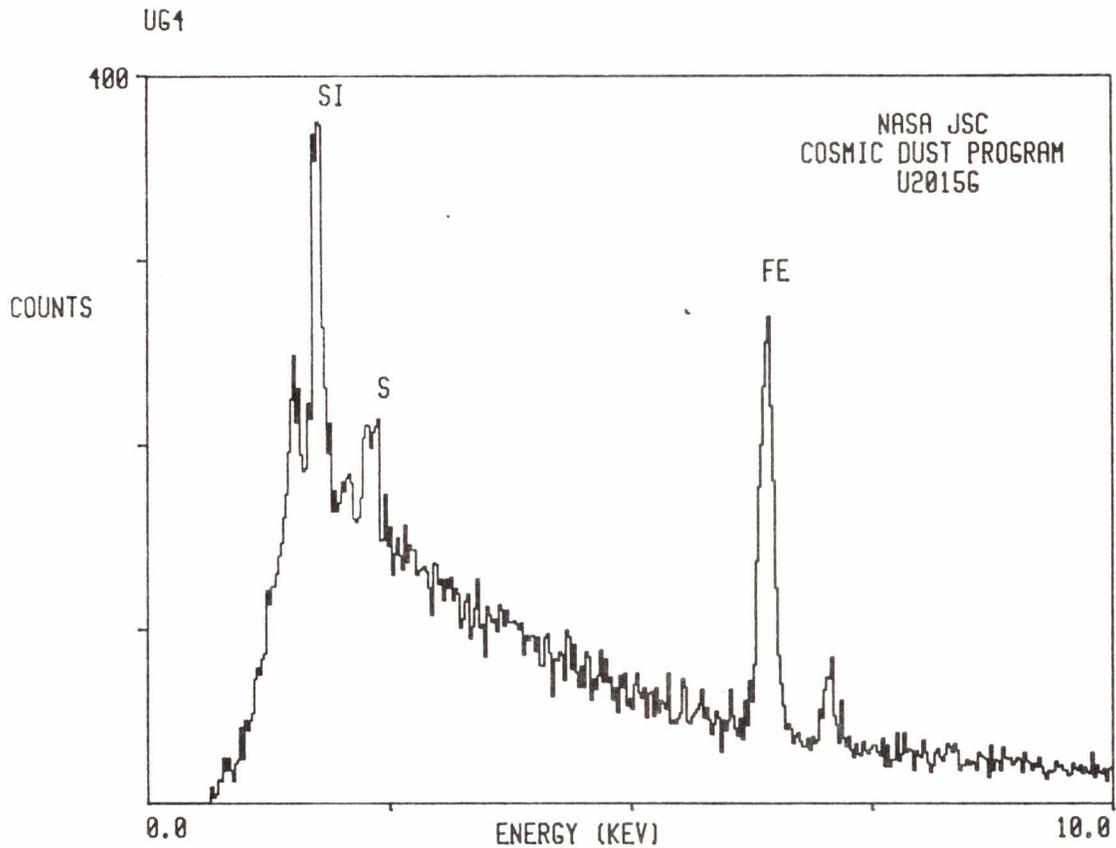


U2015G4

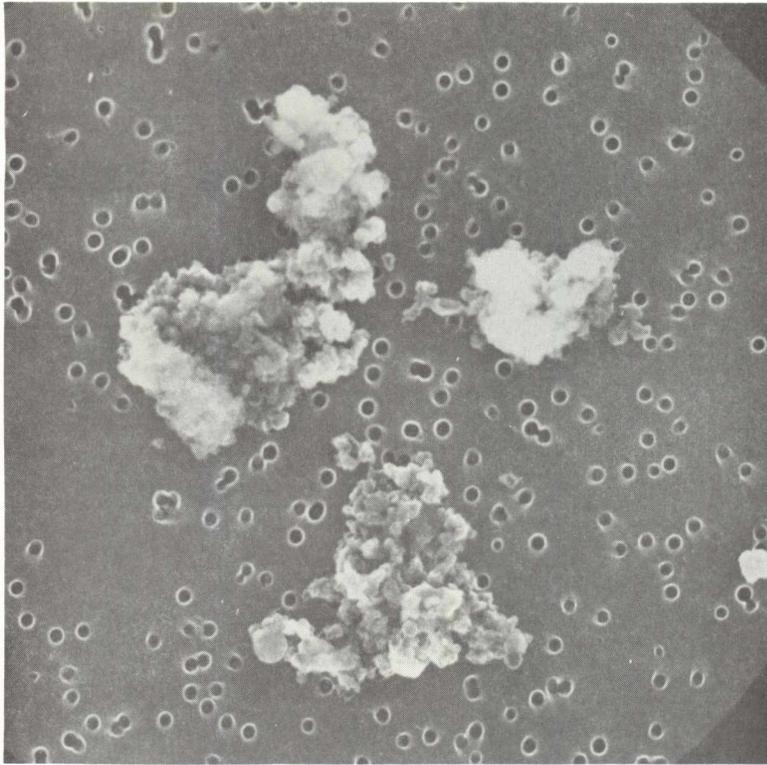


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
21x12	I	O
<u>COLOR</u>		<u>LUSTER</u>
Brown to Black		SM/D
<u>TYPE</u>	<u>COMMENTS</u>	
C?	Seems to be damage from electron beam	

S-85-35989



U2015G5



SIZE SHAPE TRANS.

Largest is
10x5 I O

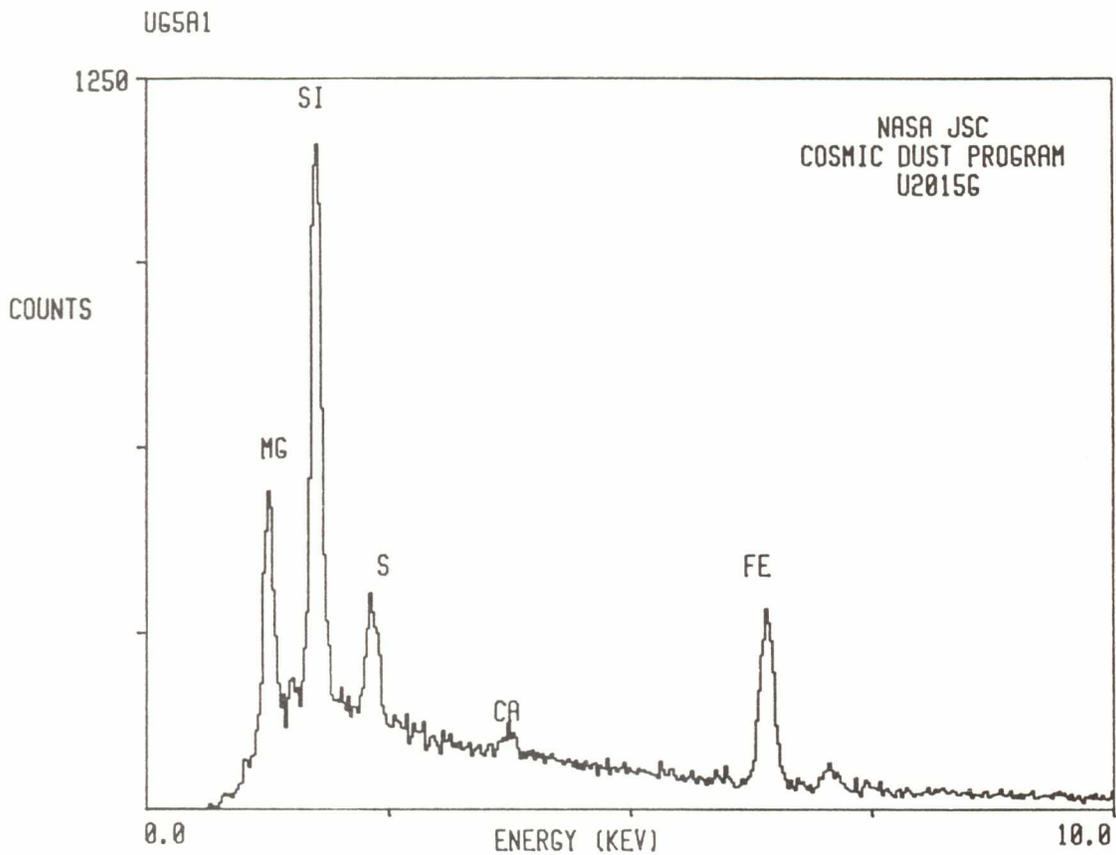
_____ COLOR _____ LUSTER

Black SM/D

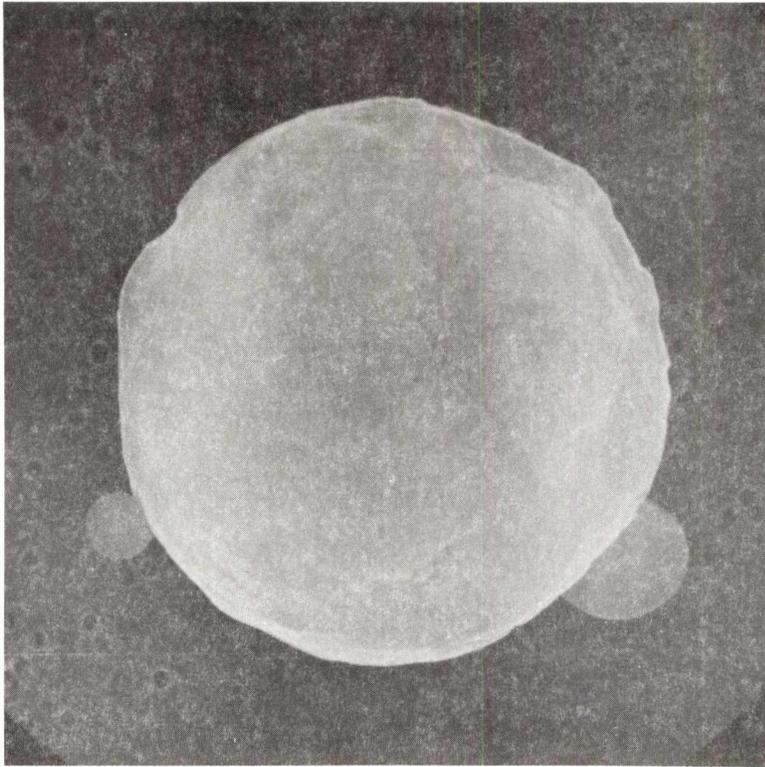
TYPE COMMENTS

C Group of 3
associated
particles with the
same basic
composition

S-85-35988

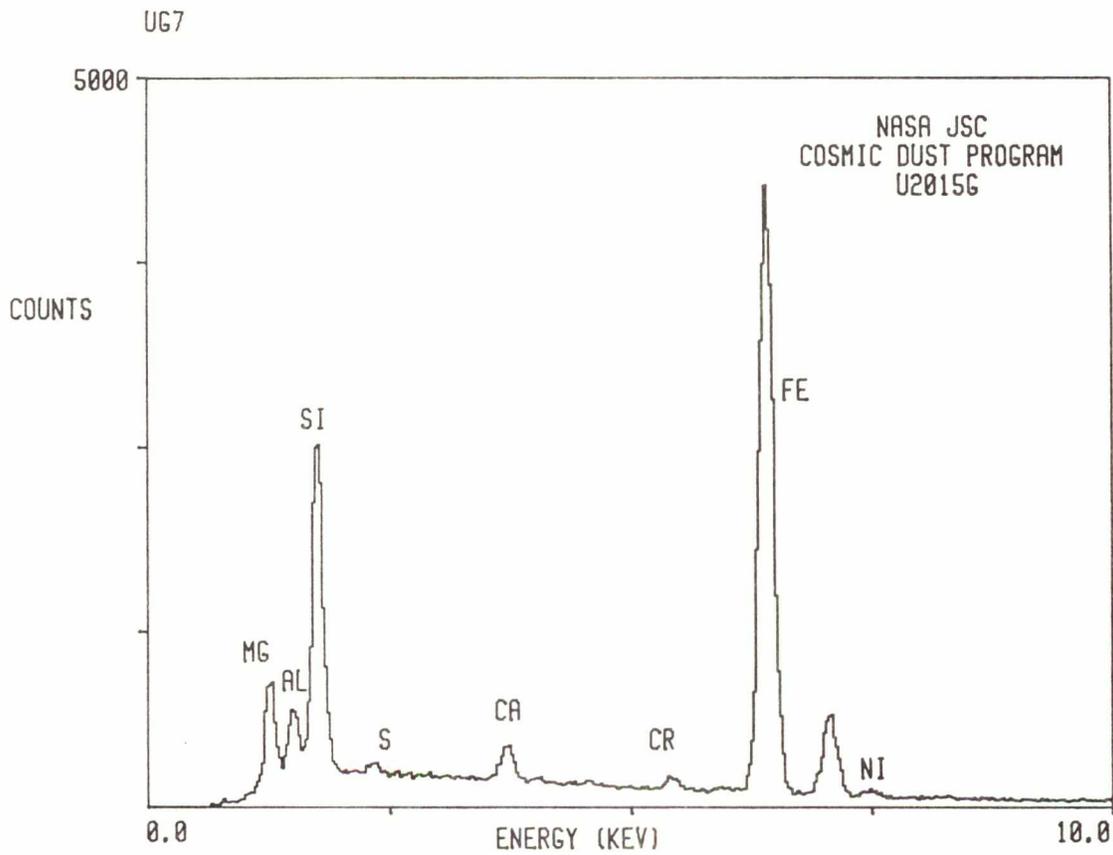


U2015G7

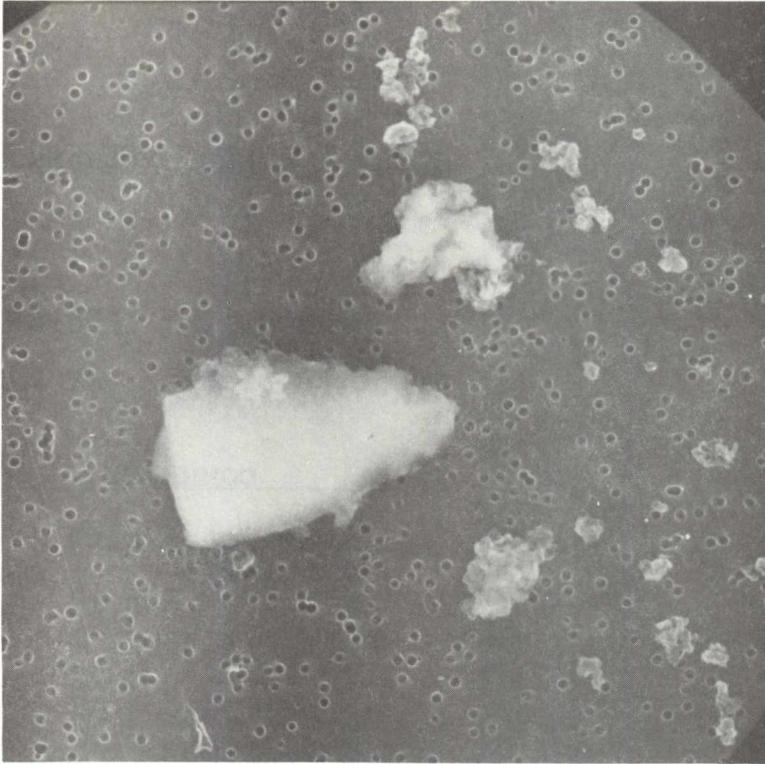


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
13	S	O
<u>COLOR</u>		<u>LUSTER</u>
Brown to Black		M/V
<u>TYPE</u>	<u>COMMENTS</u>	
C		

S-85-35986

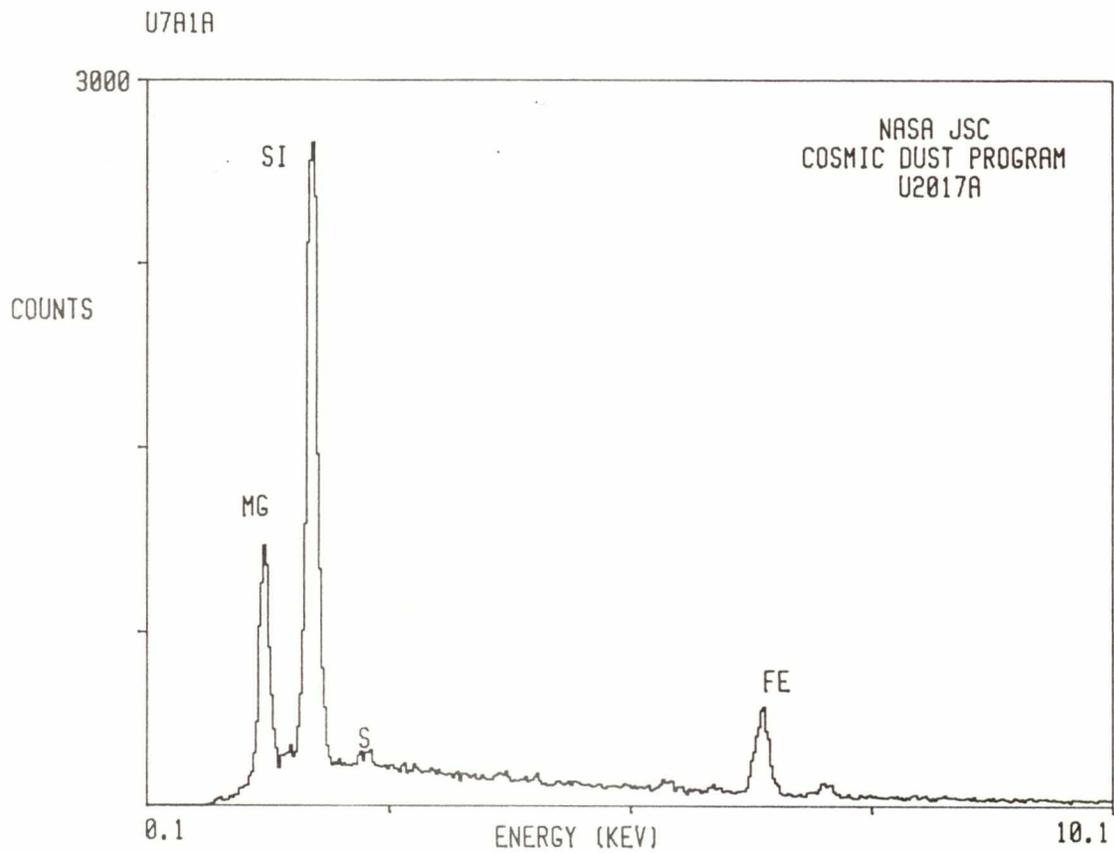


U2017A1

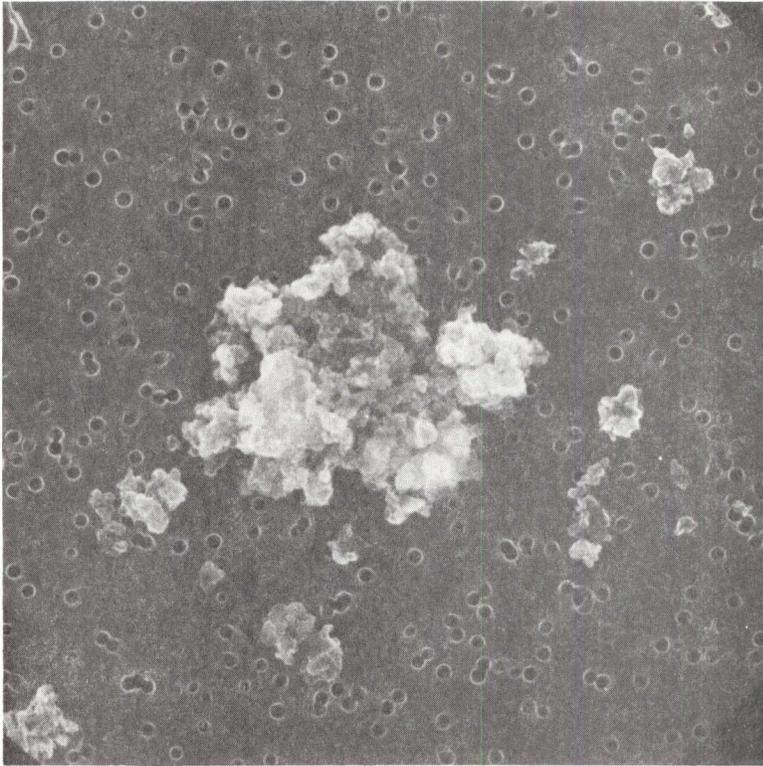


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
14	I	O
<u>COLOR</u>		<u>LUSTER</u>
Bronze		SM/M
<u>TYPE</u>	<u>COMMENTS</u>	
C	Associated with A2, A12	

S-85-36038



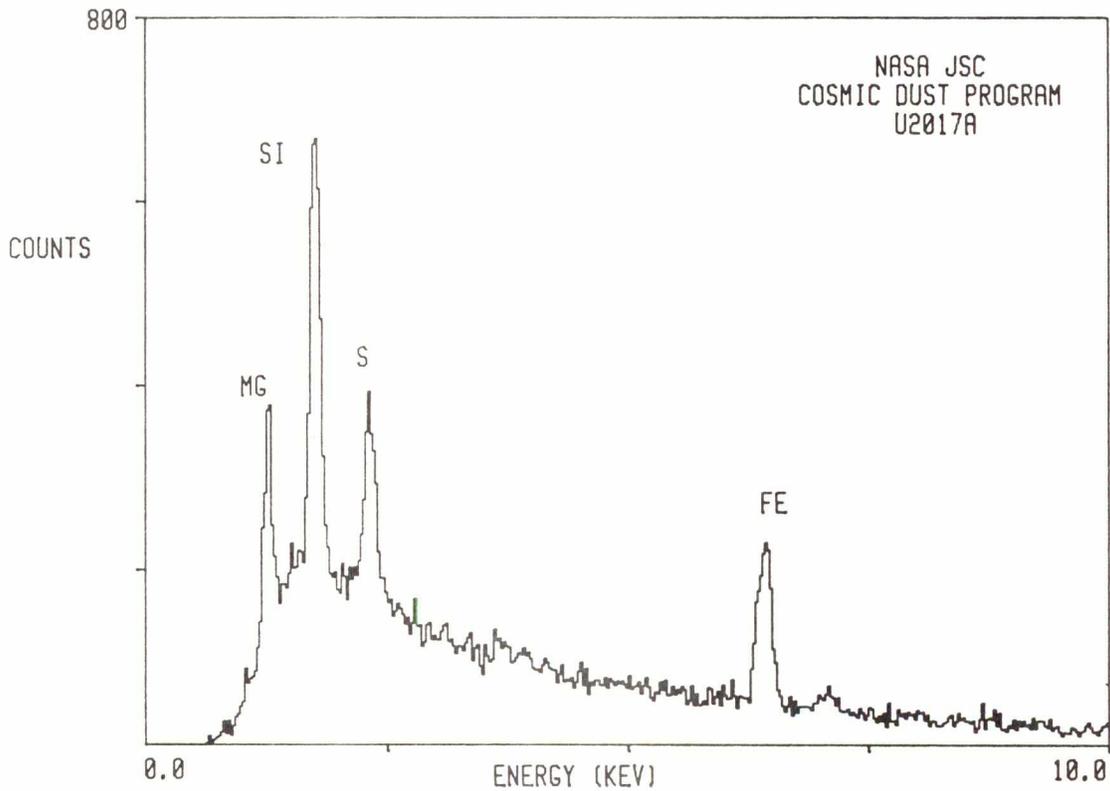
U2017A2



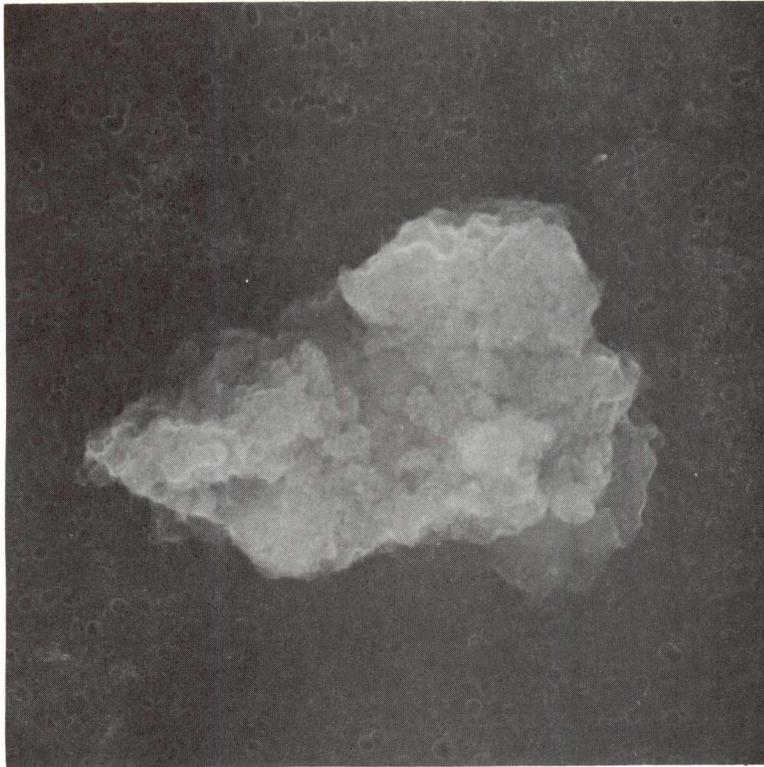
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
12	I	O
<u>COLOR</u>		<u>LUSTER</u>
Green to Black		SV/D
<u>TYPE</u>	<u>COMMENTS</u>	
C	Associated with A1, A12	

S-85-36039

U7A2

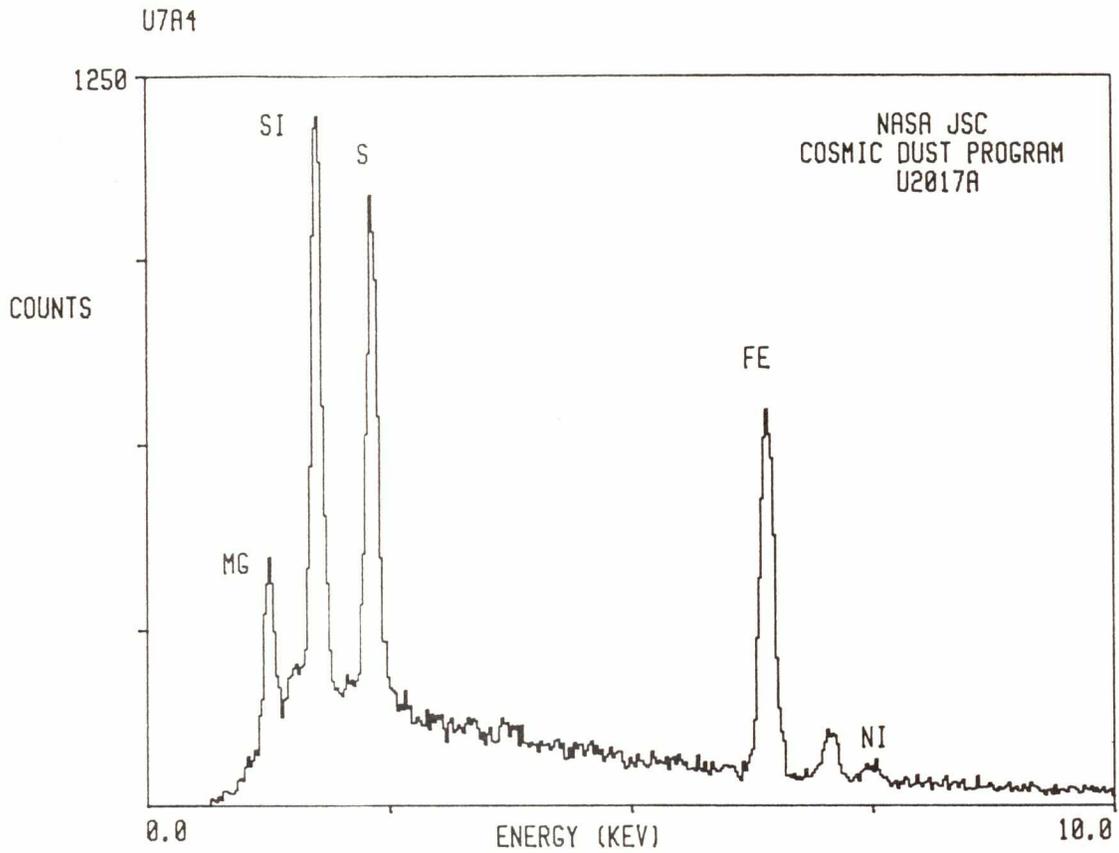


U2017A4

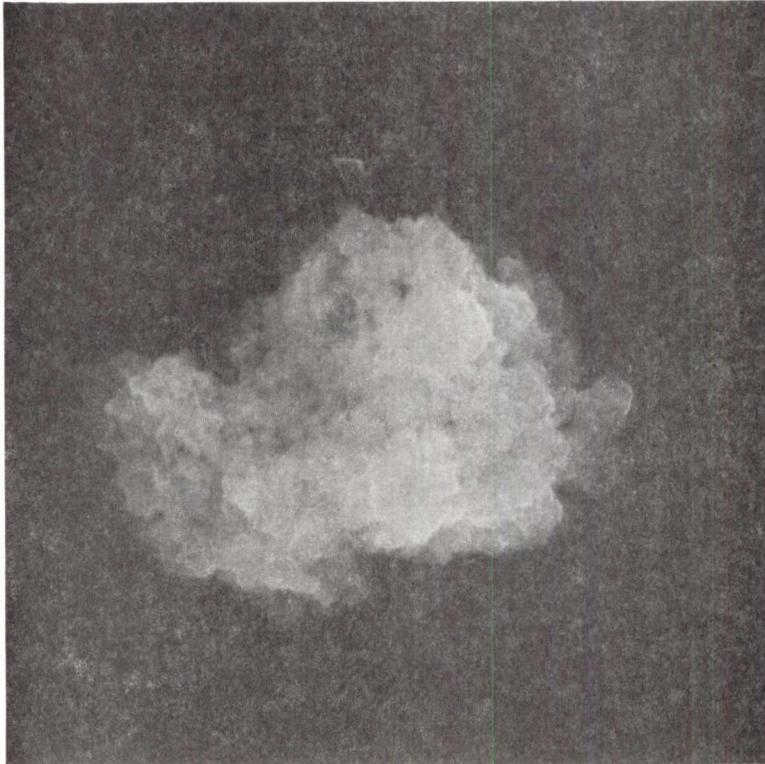


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
18x10	I	O
<u>COLOR</u>		<u>LUSTER</u>
Bronze to Black		D/SM
<u>TYPE</u>	<u>COMMENTS</u>	
C		

S-85-36041

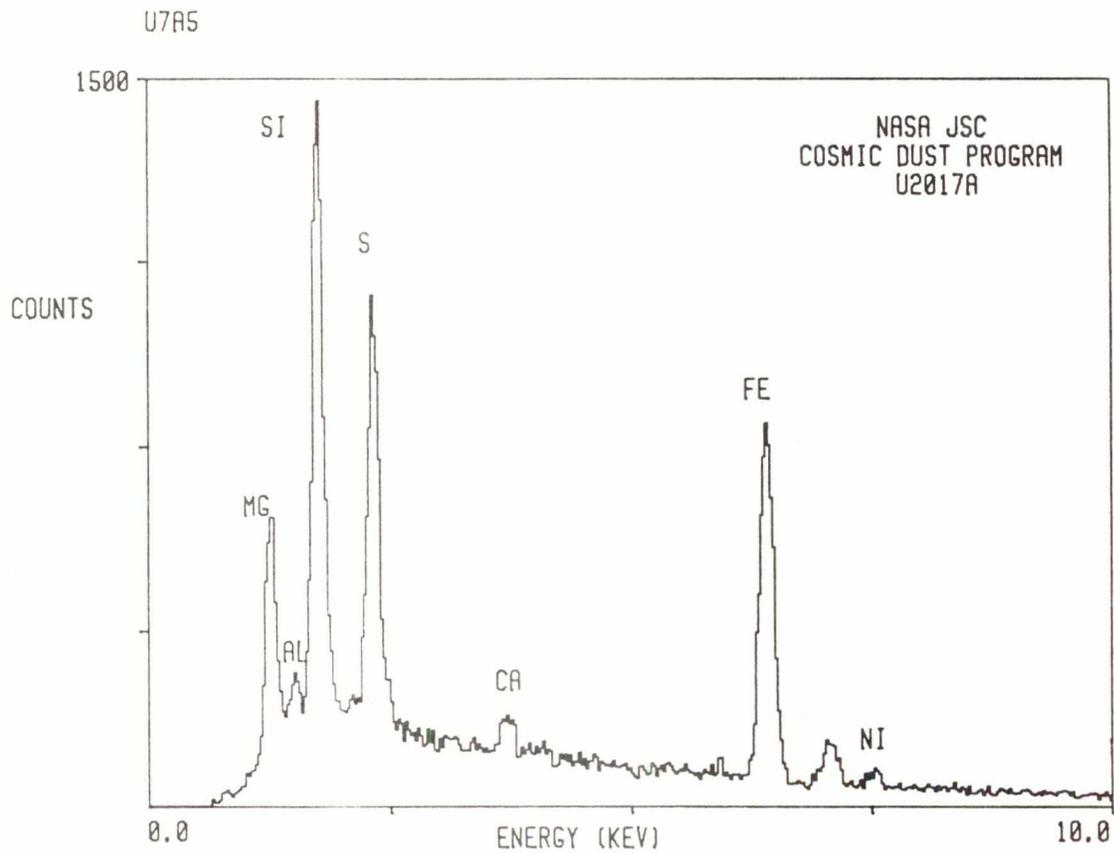


U2017A5

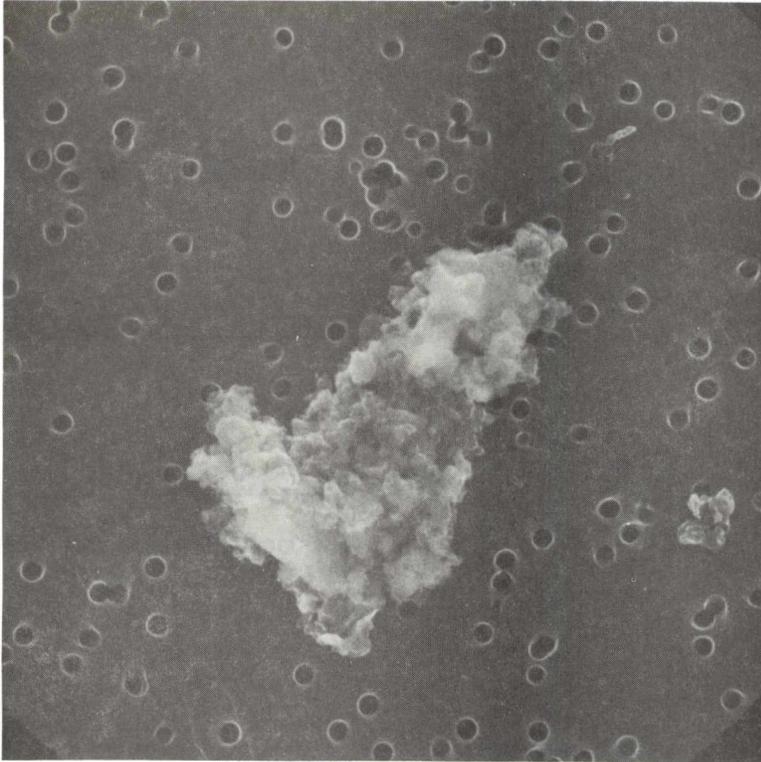


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
15x9	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black to Bronze		D/SM
<u>TYPE</u>	<u>COMMENTS</u>	
C		

S-85-36042



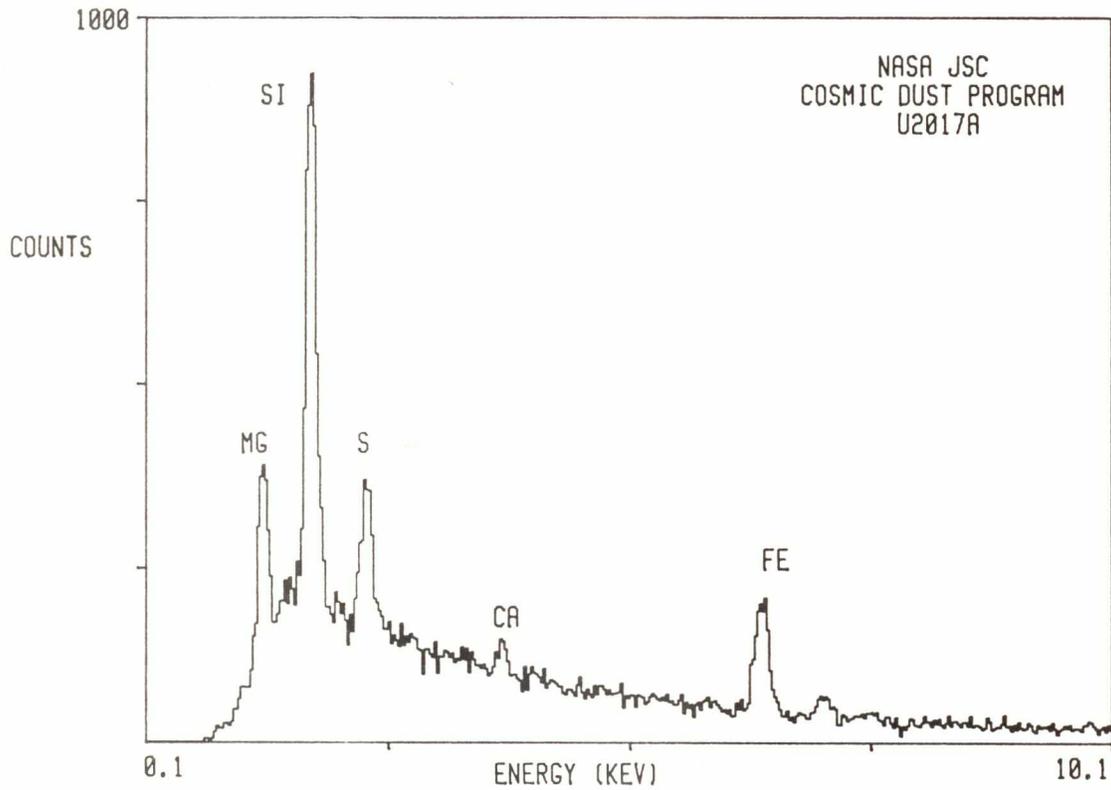
U2017A12



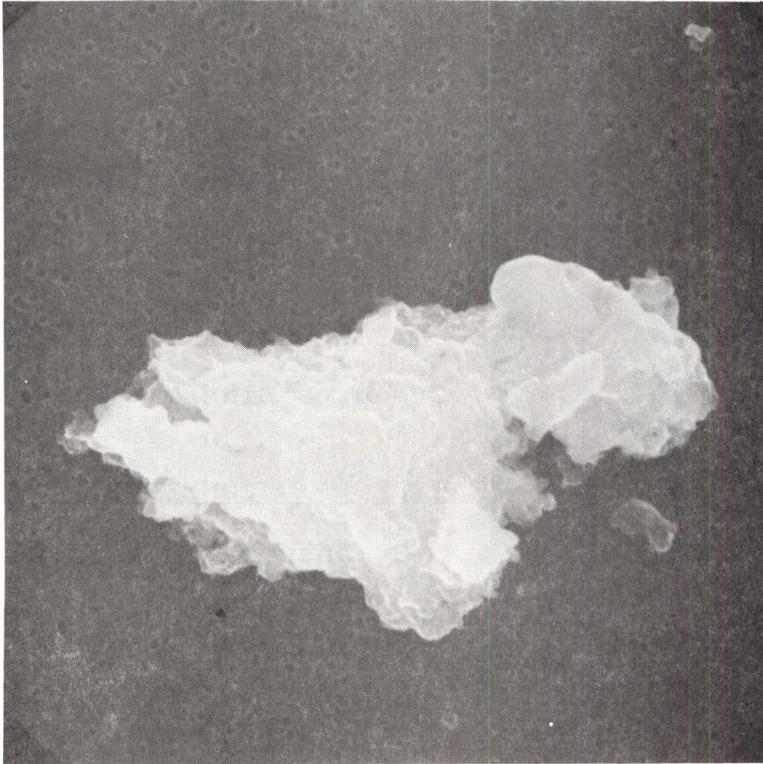
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
9x4	I	O
<u>COLOR</u>		<u>LUSTER</u>
Green to Black		SV/D
<u>TYPE</u>	<u>COMMENTS</u>	
C	Associated with A1 and A2	

S-85-36048

U7A12

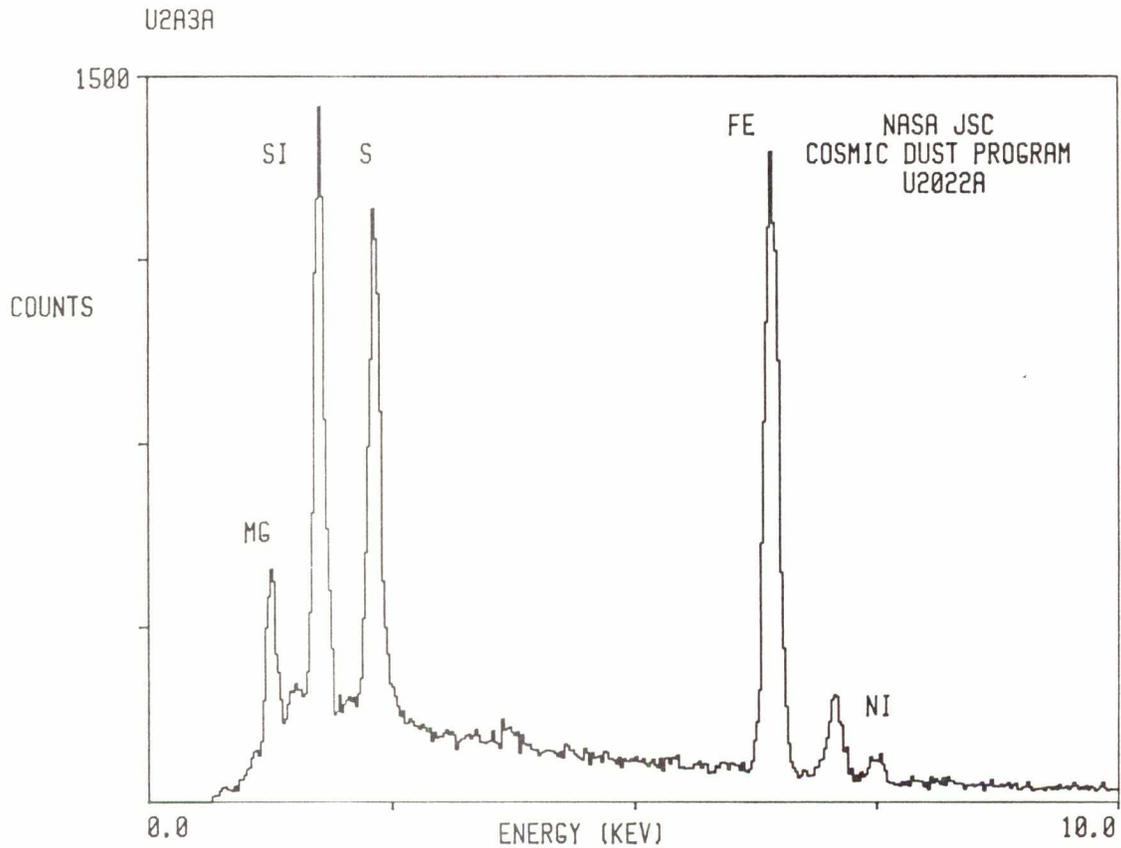


U2022A3

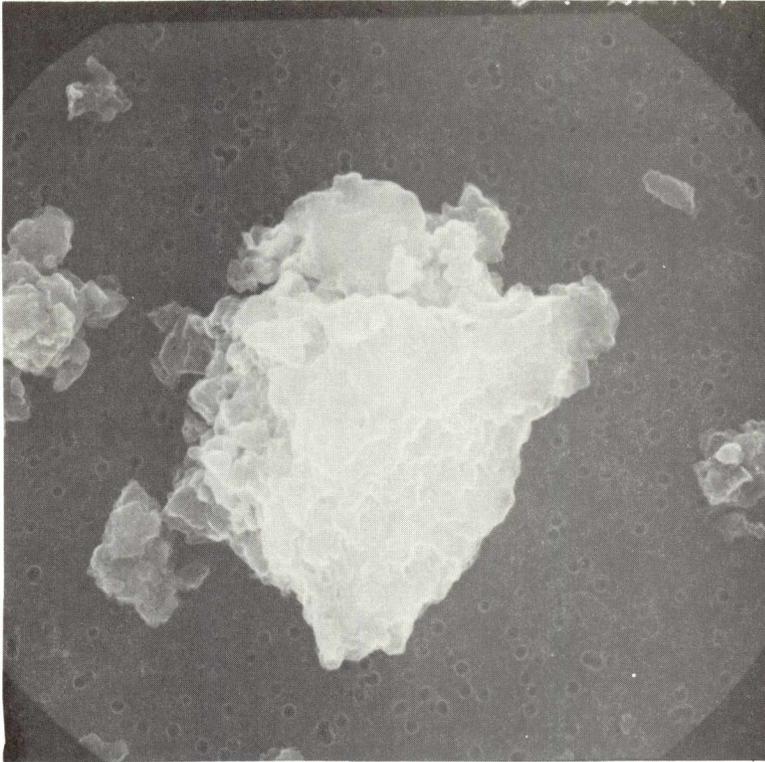


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
15x7	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black		SM/SV
<u>TYPE</u>	<u>COMMENTS</u>	
C	Associated with U2022A4	

S-85-36013

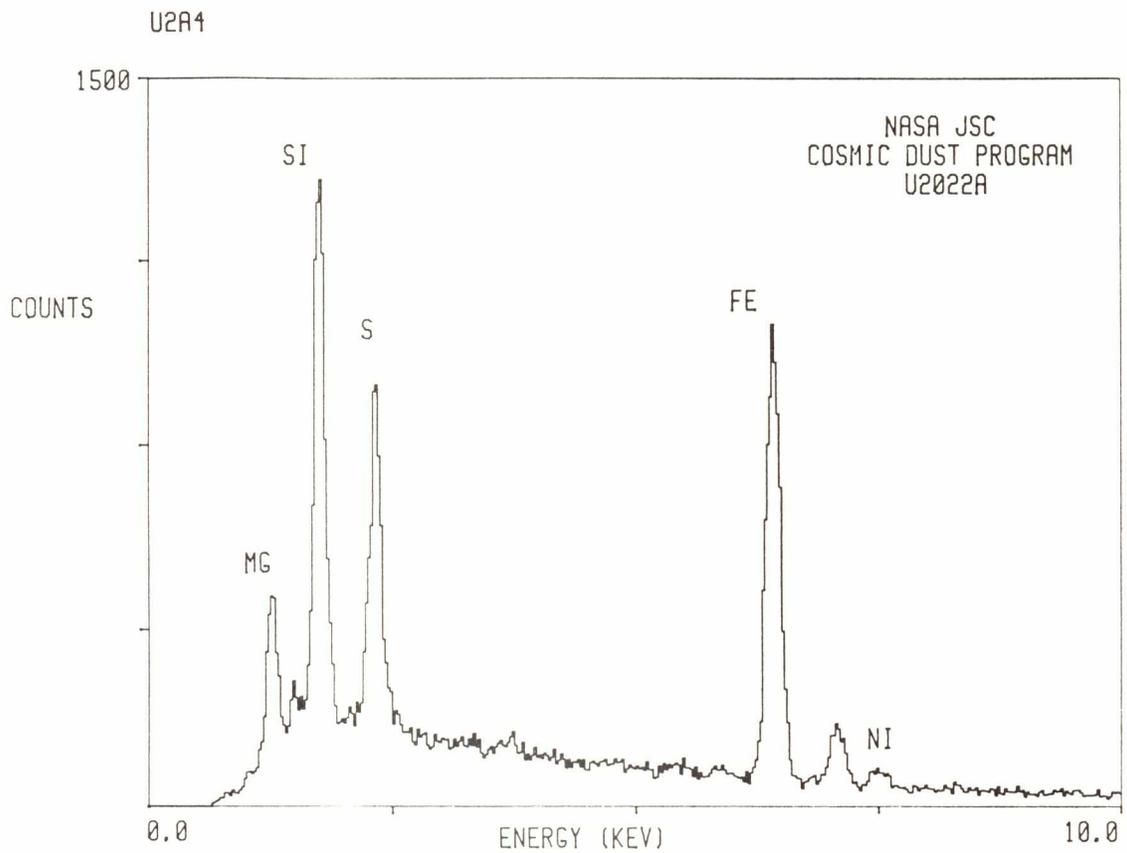


U2022A4



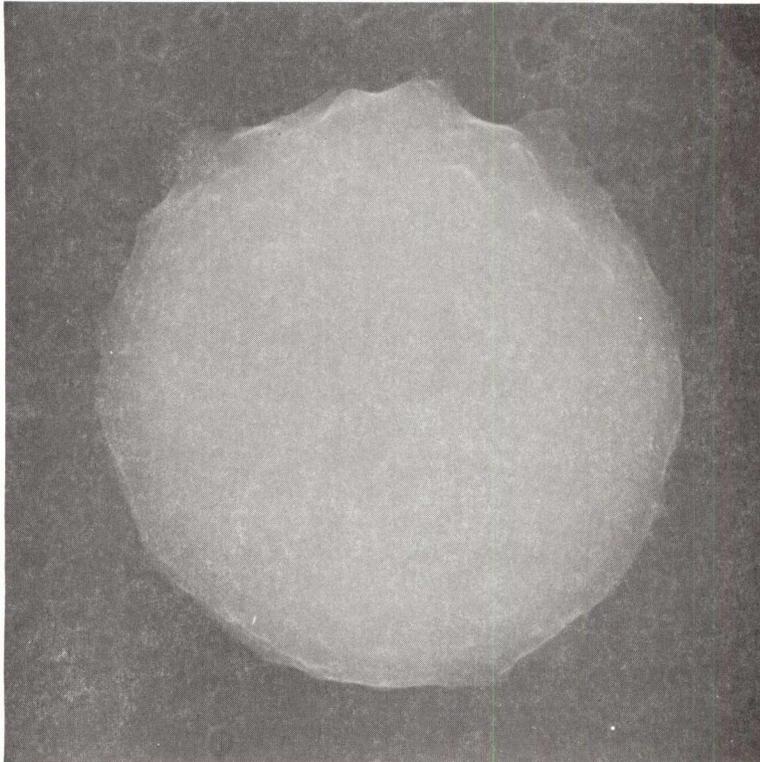
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
8	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black		SM/SV
<u>TYPE</u>	<u>COMMENTS</u>	
C	Associated with U2022A3	

S-85-35014



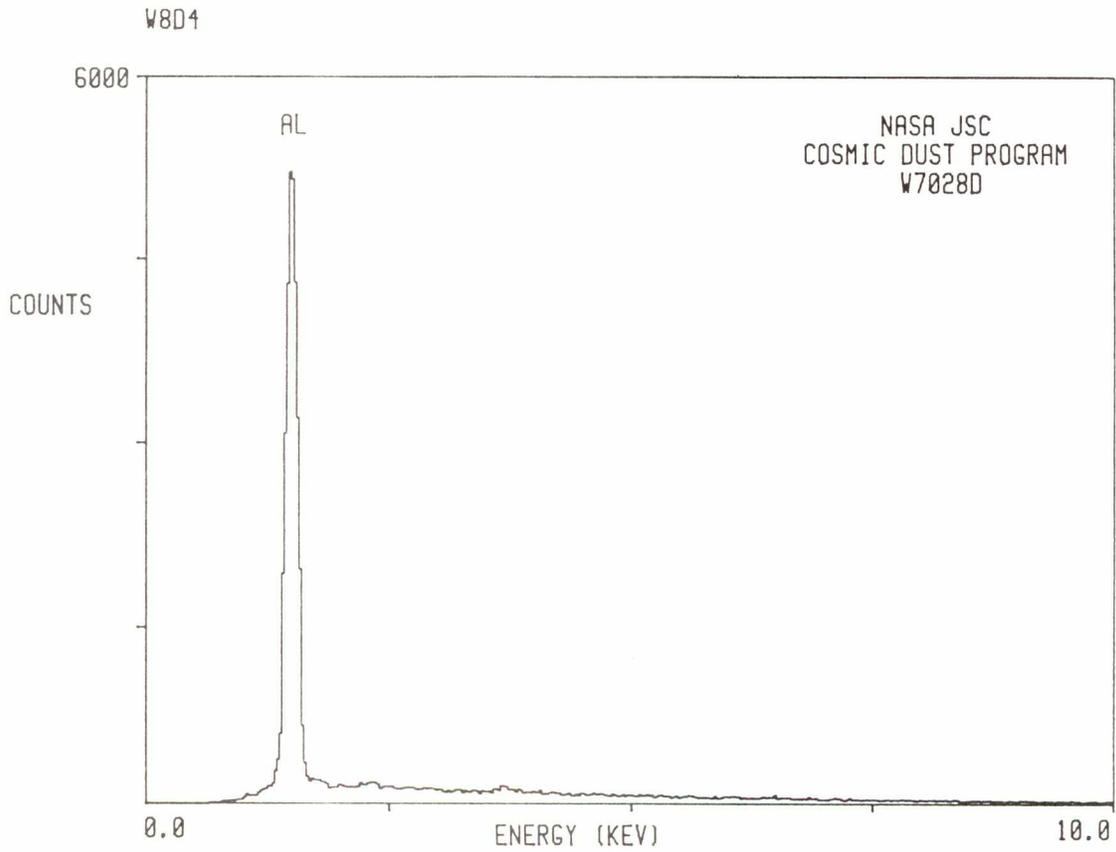
ALUMINUM OXIDE SPHERES

W7028D4

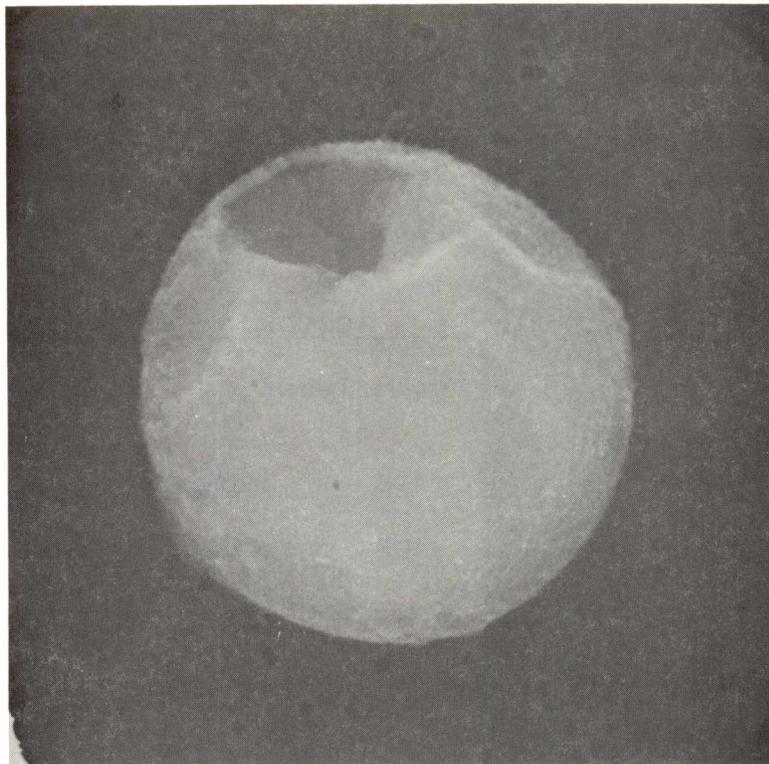


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
8	S	O
<u>COLOR</u>		<u>LUSTER</u>
Black and Yellow		SV
<u>TYPE</u>	<u>COMMENTS</u>	
AOS		

S-85-36005

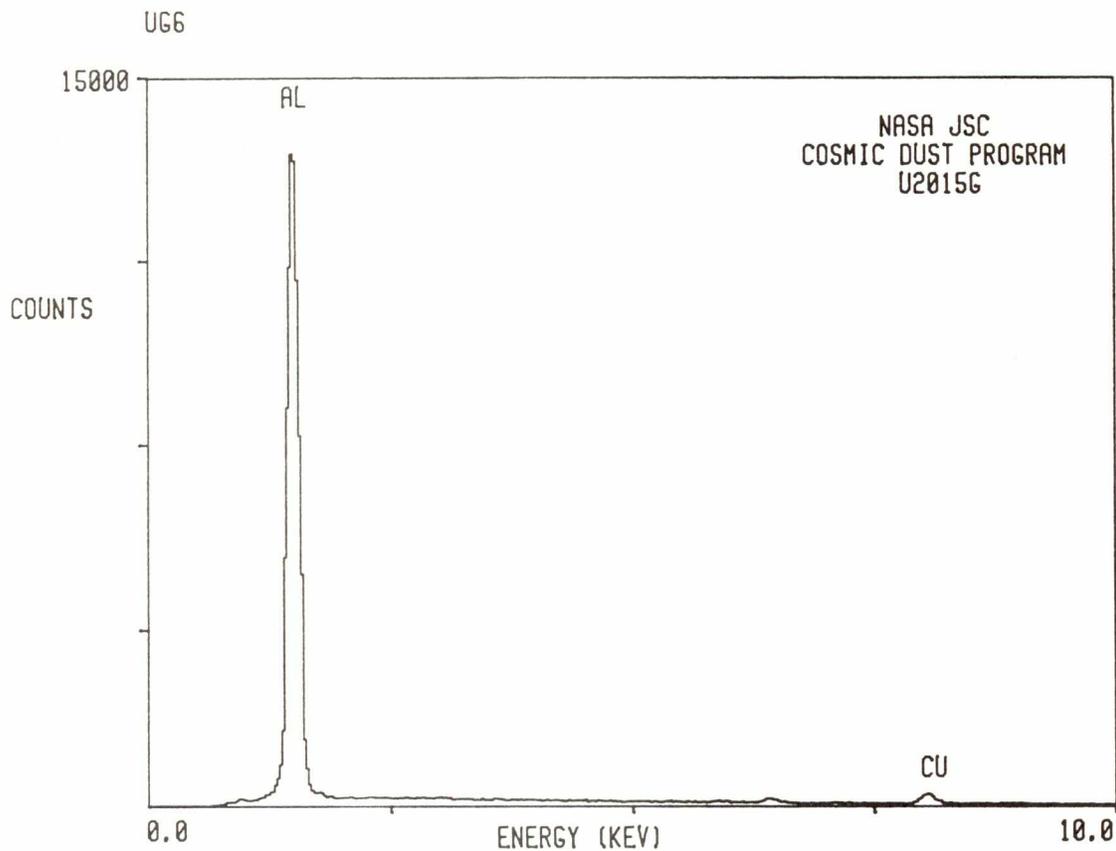


U2015G6

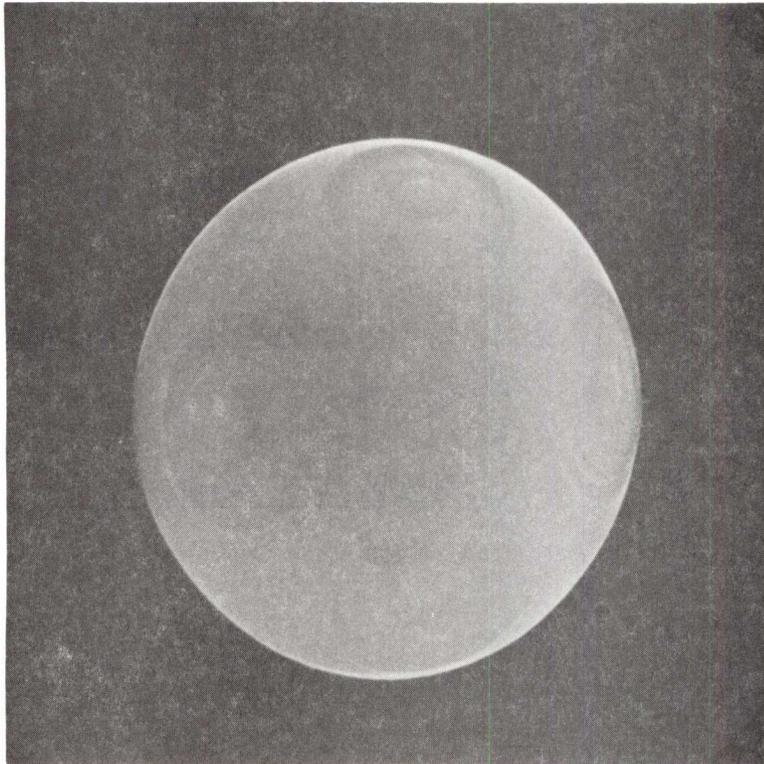


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
12	S	O
<u>COLOR</u>		<u>LUSTER</u>
Black		V
<u>TYPE</u>	<u>COMMENTS</u>	
AOS		

S-85-35987



U2017A9



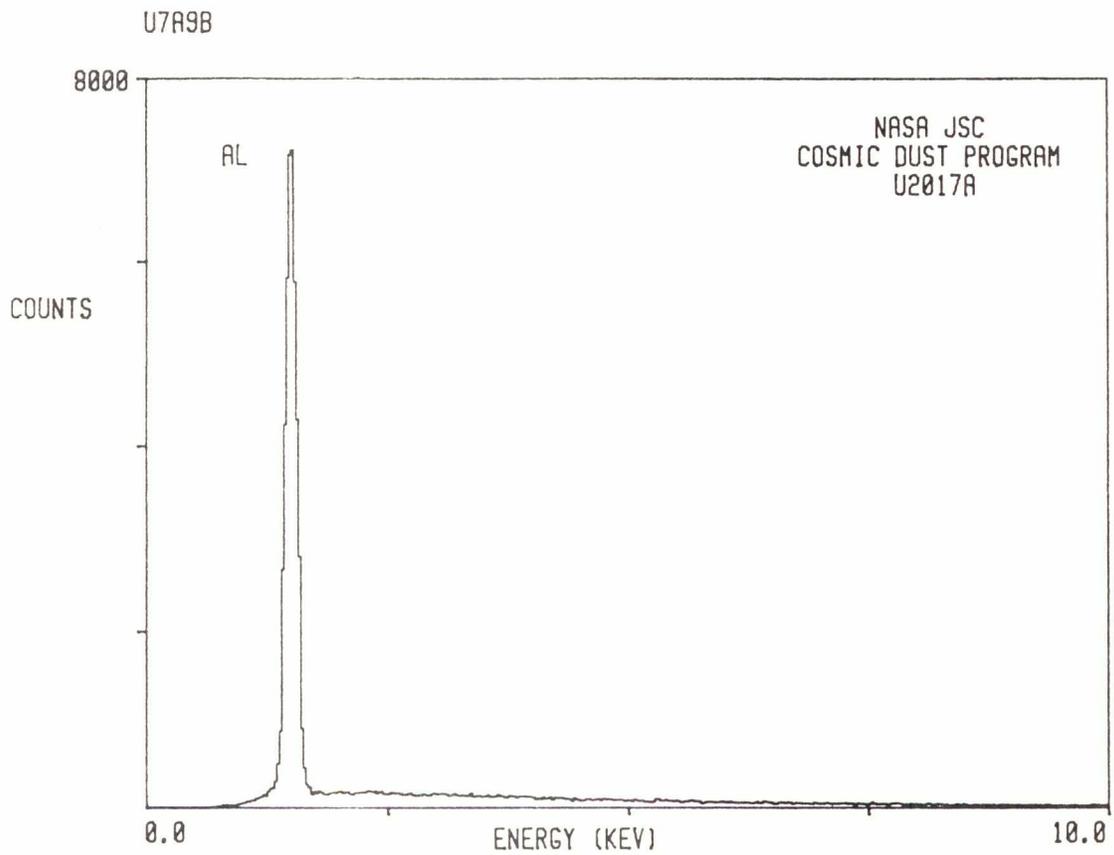
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
10	S	T

<u>COLOR</u>	<u>LUSTER</u>
Colorless	V

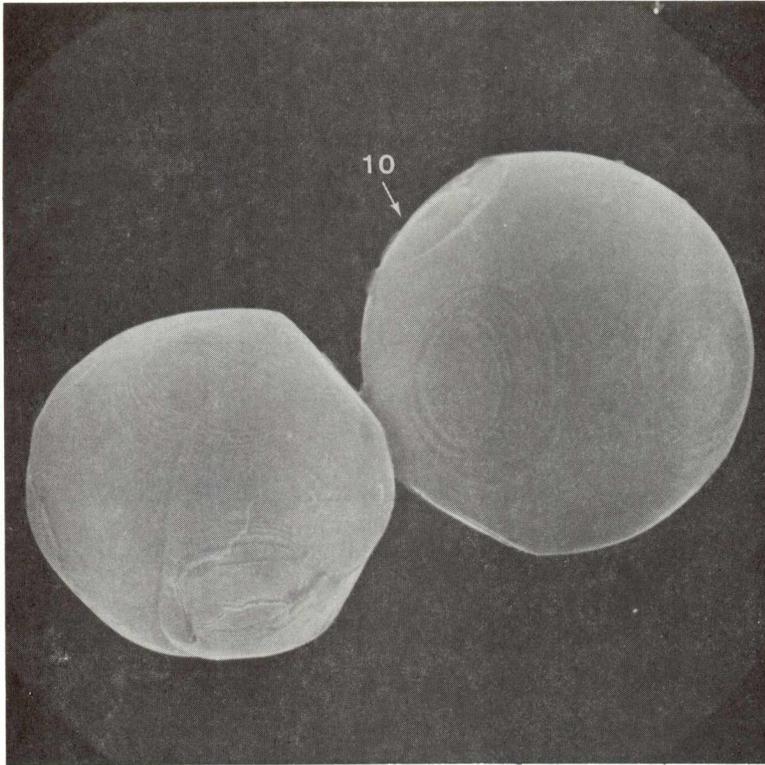
<u>TYPE</u>	<u>COMMENTS</u>
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AOS	Located adjacent to A10 and A11 on mount
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S-85-36045

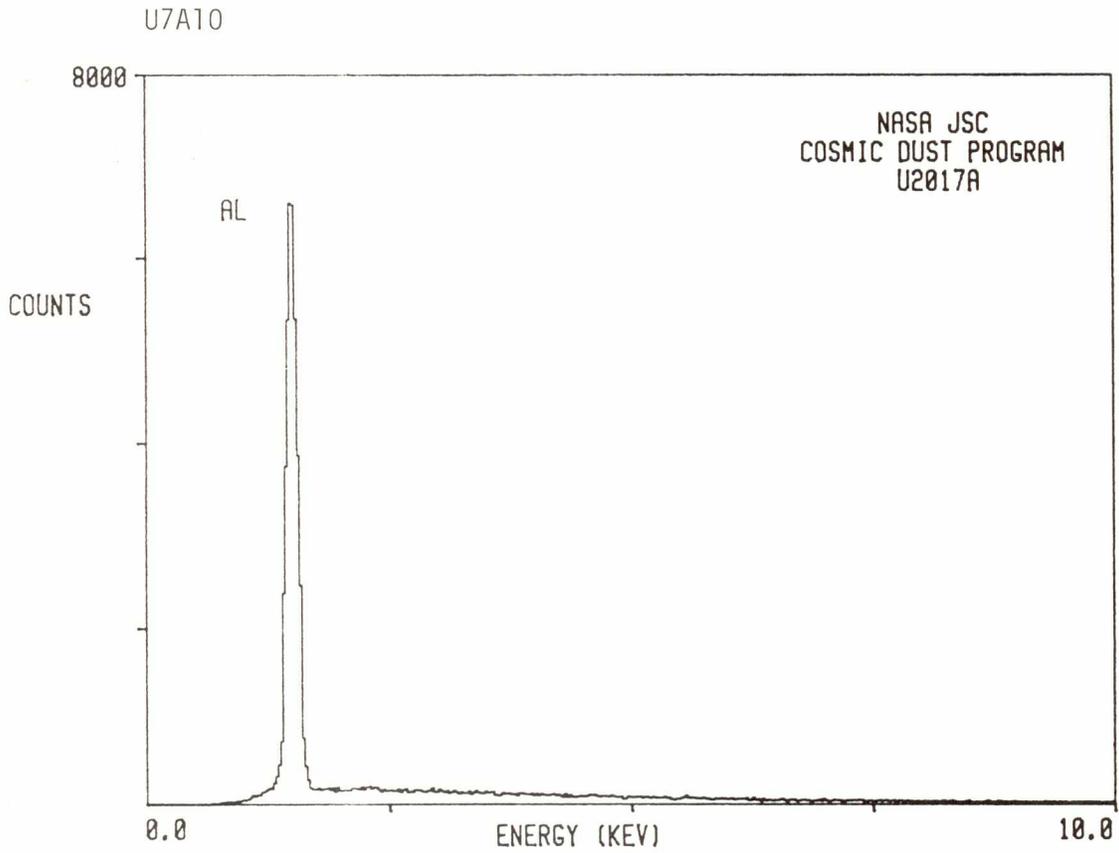


U2017A10

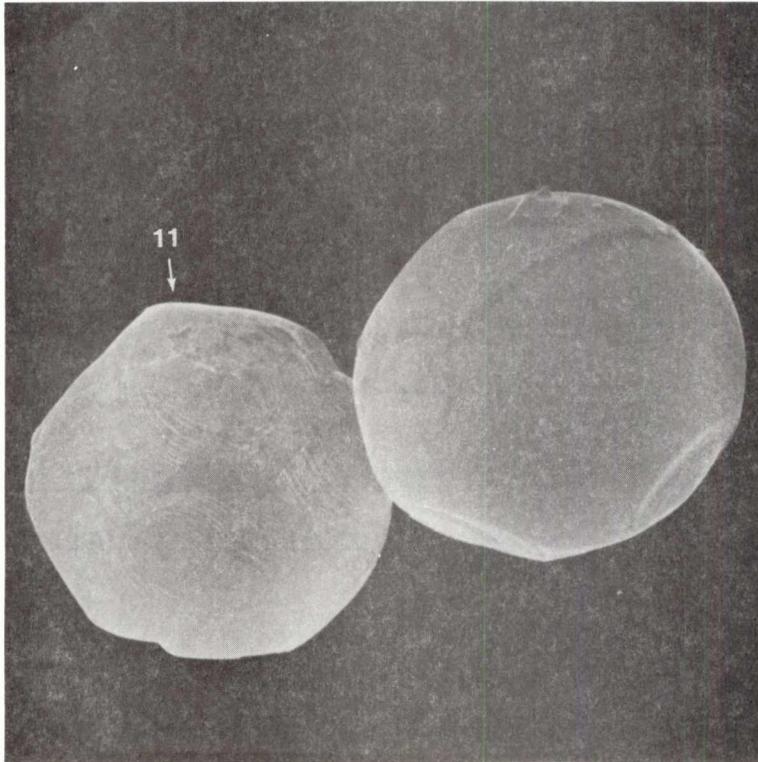


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
12	S	T
<u>COLOR</u>		<u>LUSTER</u>
Colorless		V
<u>TYPE</u>	<u>COMMENTS</u>	
AOS	Connected to All	

S-85-36046

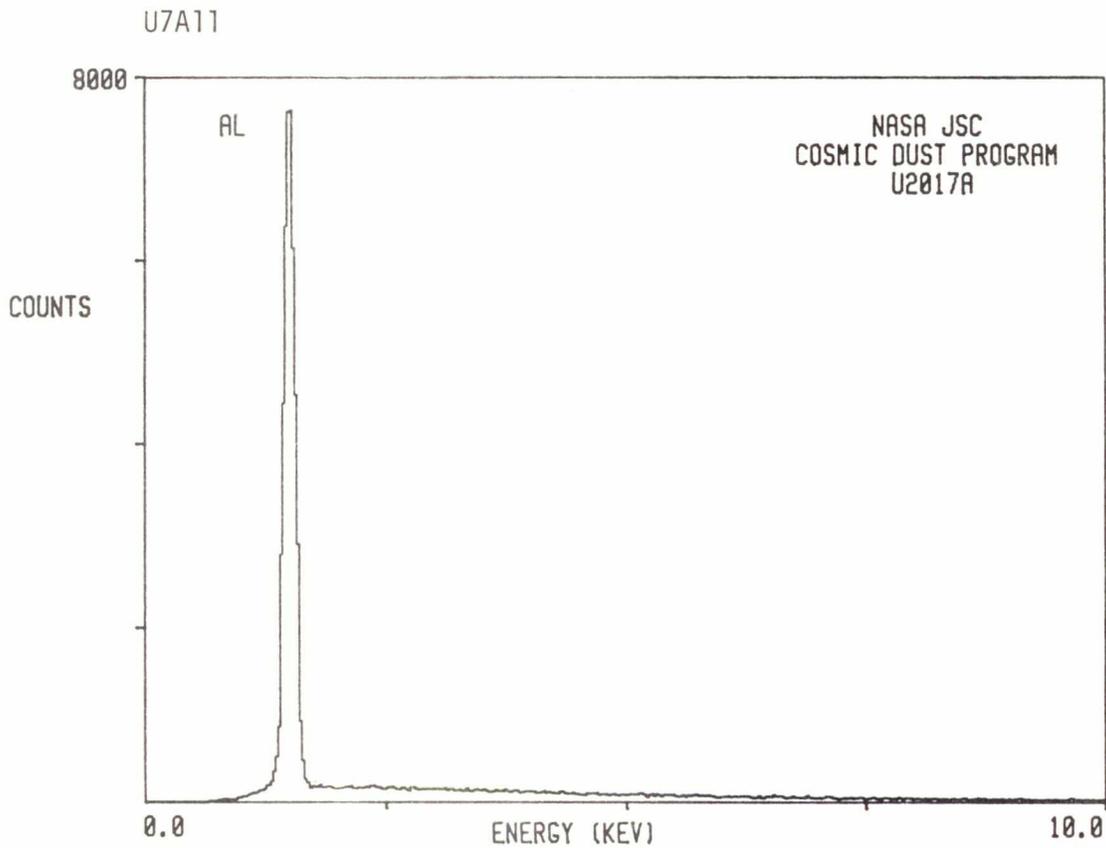


U2017A11



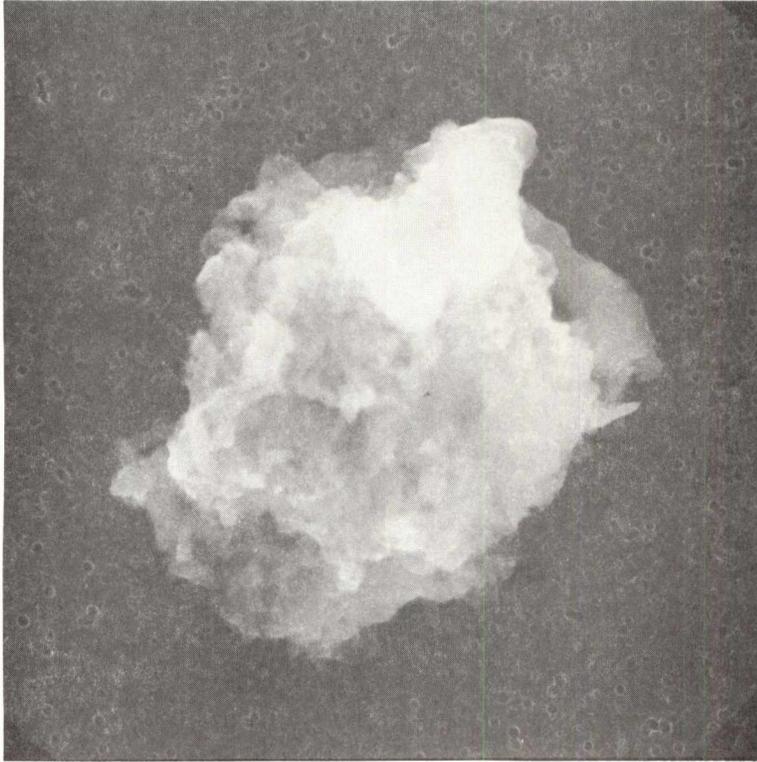
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
12	S	T
<u>COLOR</u>		<u>LUSTER</u>
Colorless		V
<u>TYPE</u>	<u>COMMENTS</u>	
AOS	Connected to A10	

S-85-36047



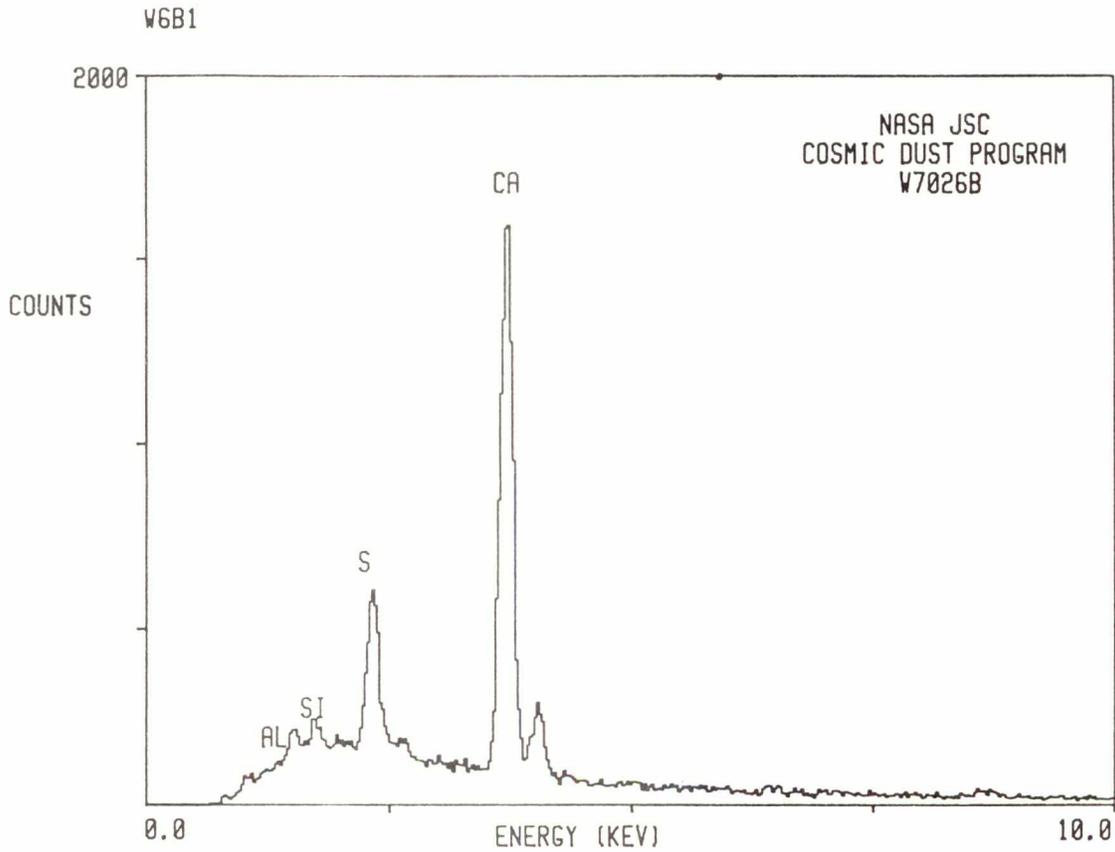
TERRESTRIAL CONTAMINATION

W7026B1



<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
22	E	O
<u>COLOR</u>		<u>LUSTER</u>
Yellow-Brown to Black		SV/D
<u>TYPE</u>	<u>COMMENTS</u>	
TCN		

S-85-36009



W7026B2



SIZE SHAPE TRANS.

15x10 I O

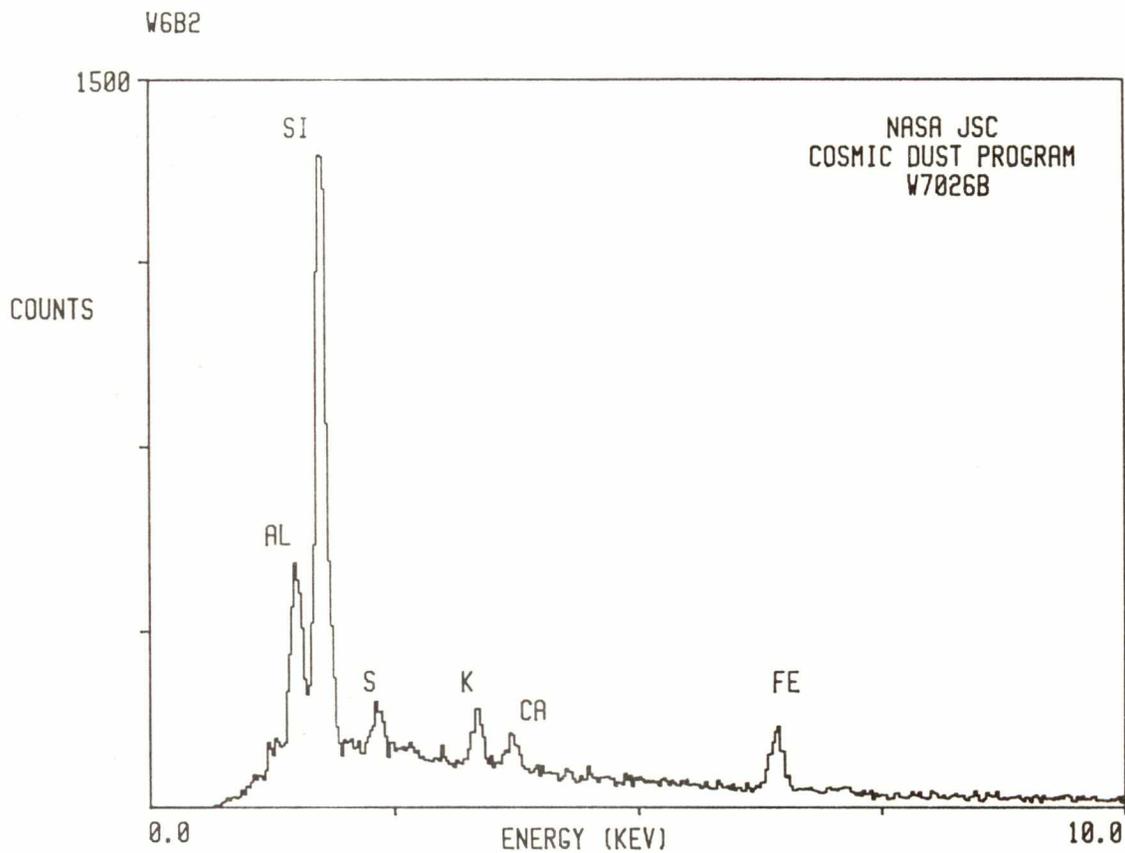
_____ COLOR _____ LUSTER

Yellow-Brown to SV/D
Black

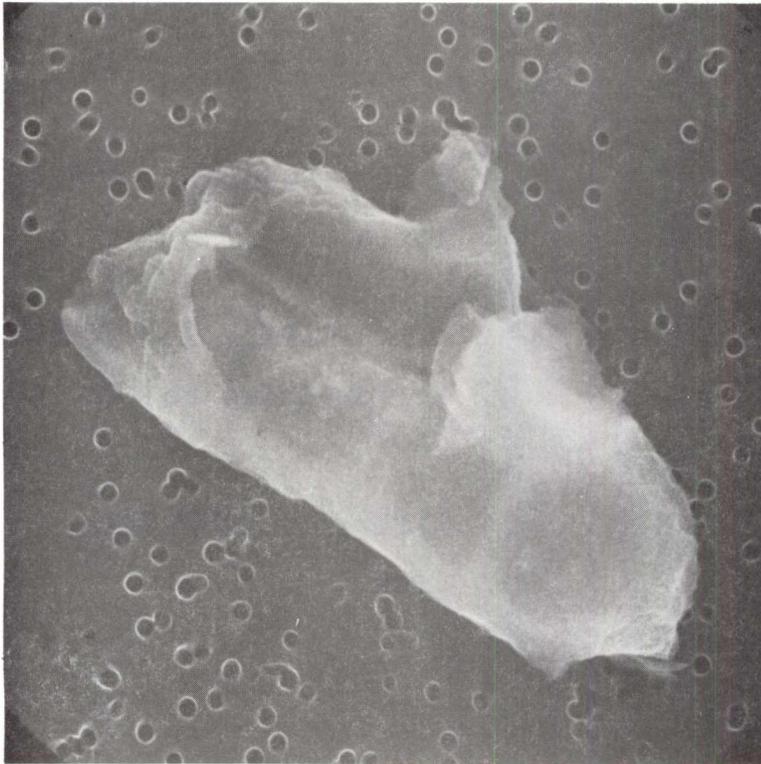
TYPE _____ COMMENTS

TCN

S-85-36010



W7028D2



SIZE SHAPE TRANS.

15x8 I O

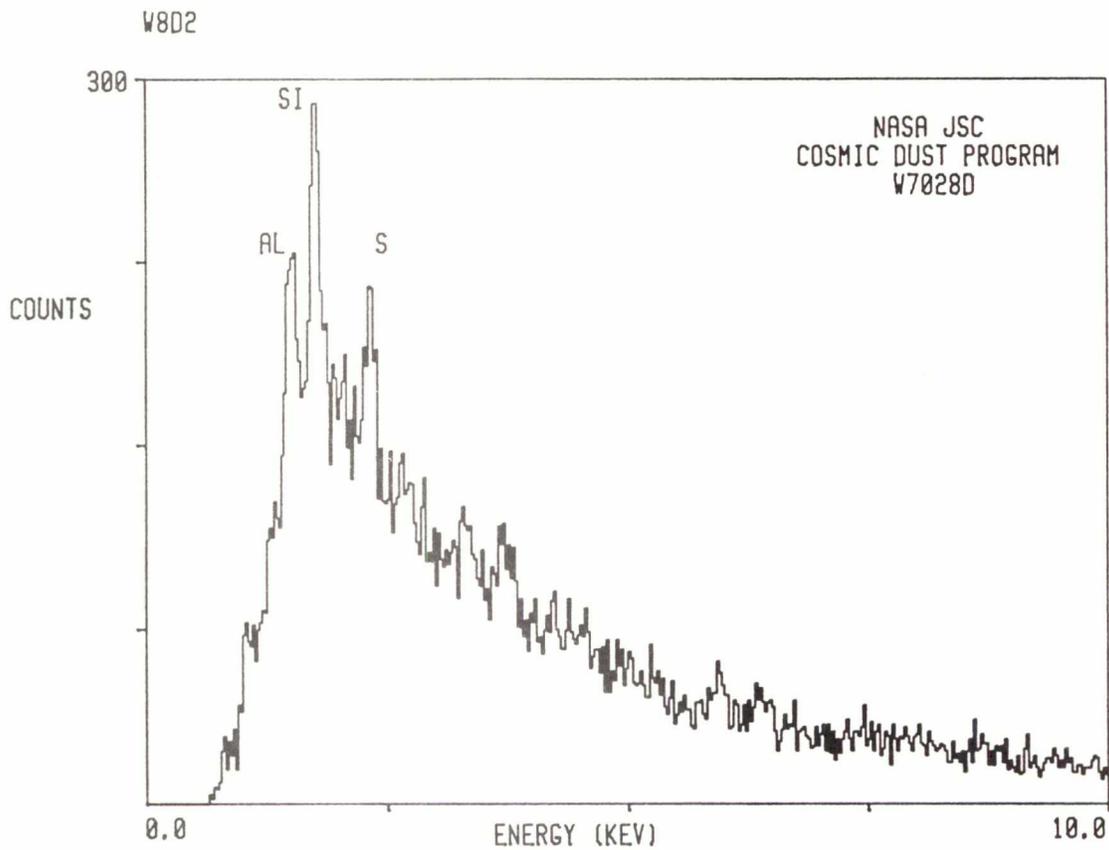
_____ COLOR _____ LUSTER

Yellow to Black SV/D

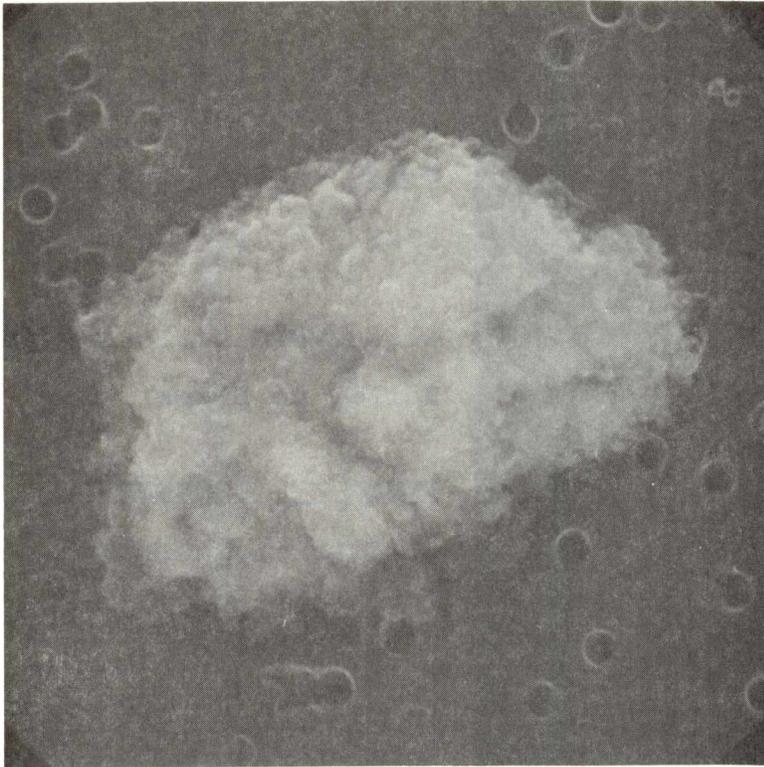
TYPE _____ COMMENTS

TCN Particle from
Prime Area #II

S-85-36003

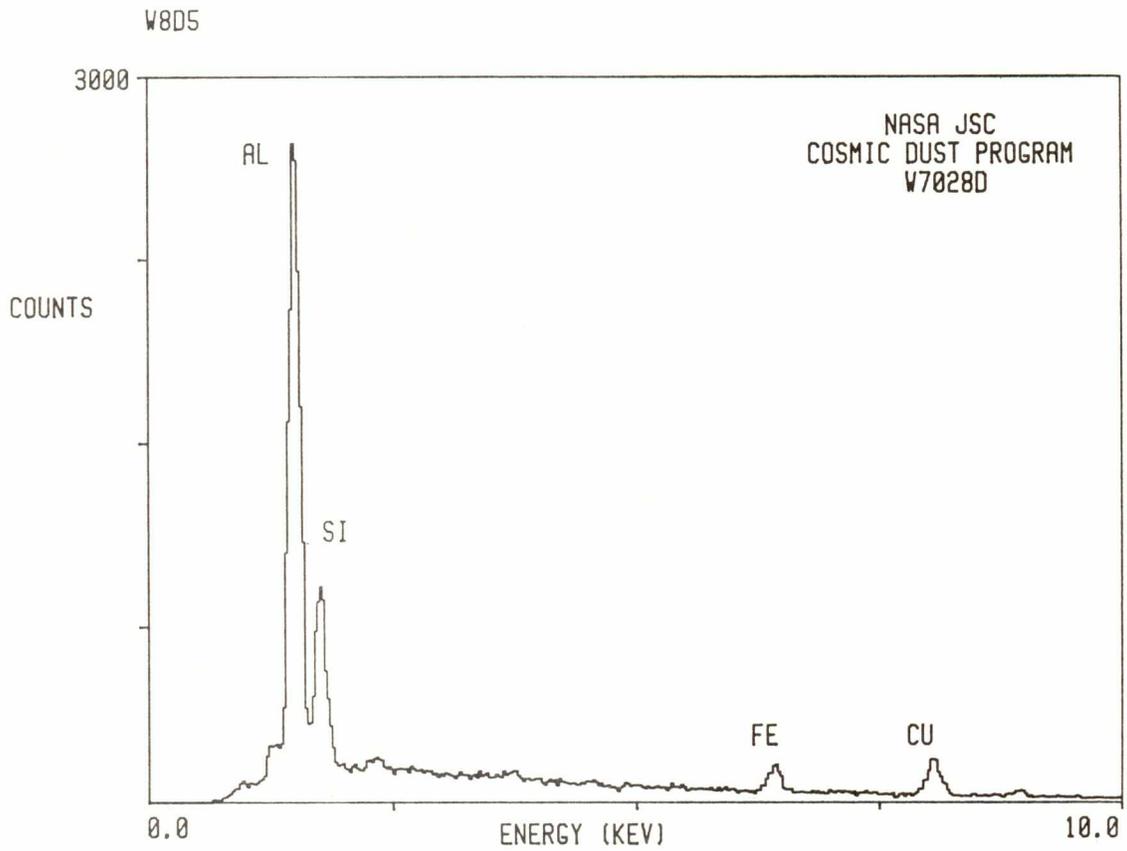


W7028D5

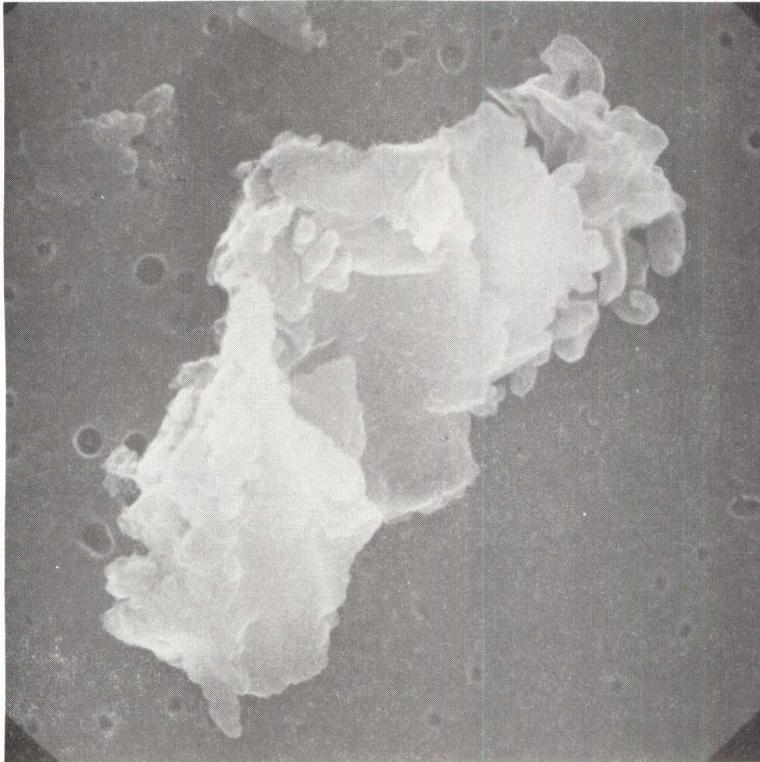


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
8x5	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black		D
<u>TYPE</u>	<u>COMMENTS</u>	
TCA		

S-85-36006



W7028D6



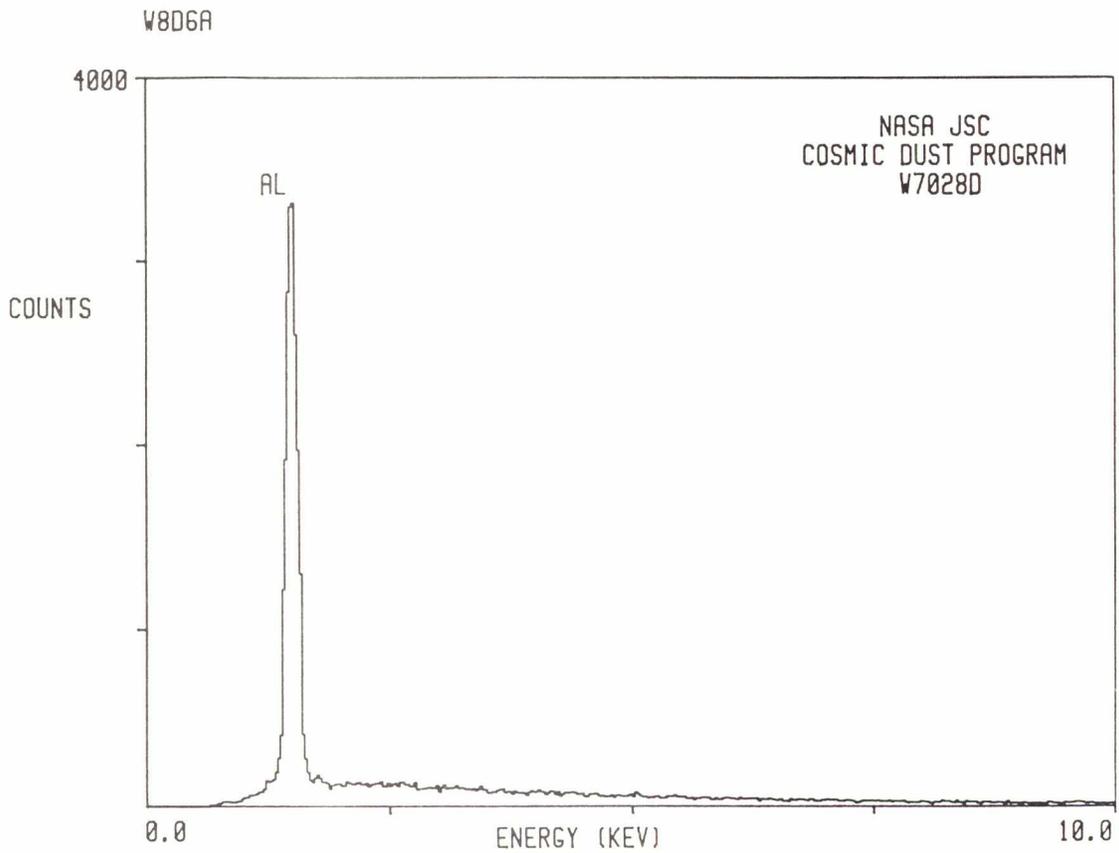
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
8x3	I	O

<u>COLOR</u>	<u>LUSTER</u>
Yellow to Black	M/D

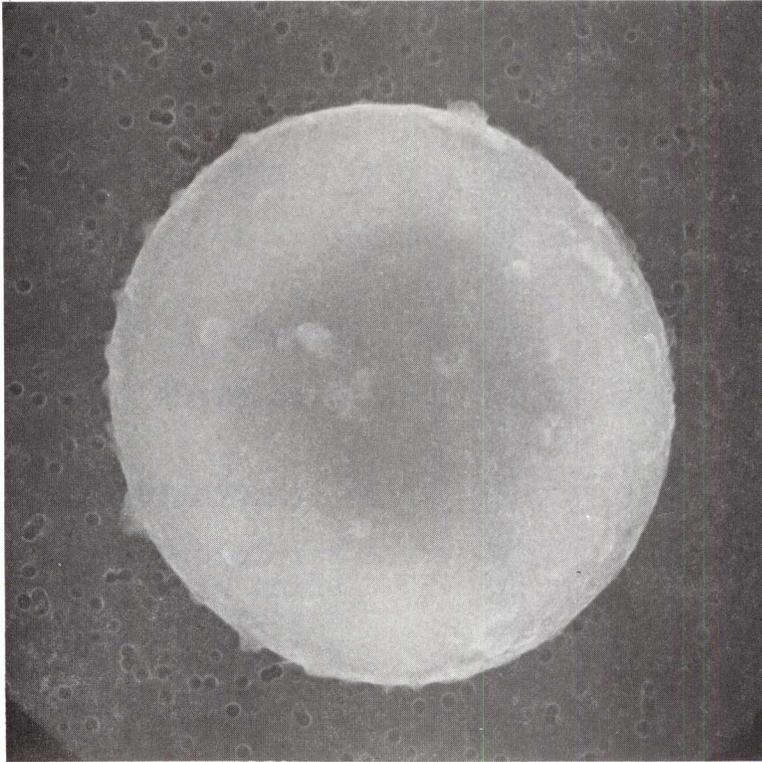
<u>TYPE</u>	<u>COMMENTS</u>
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TCA Particle from
Prime Area #IV;
associated with
W7028D7

S-85-36007

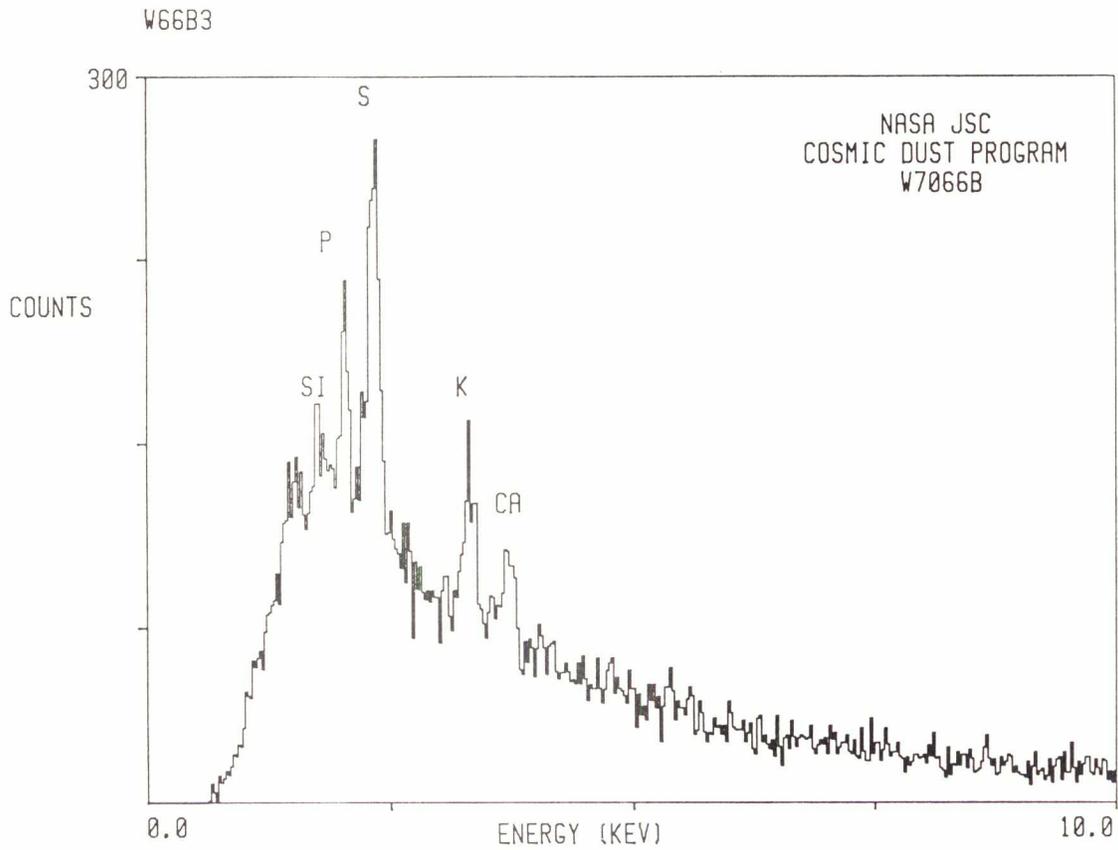


W7066B3

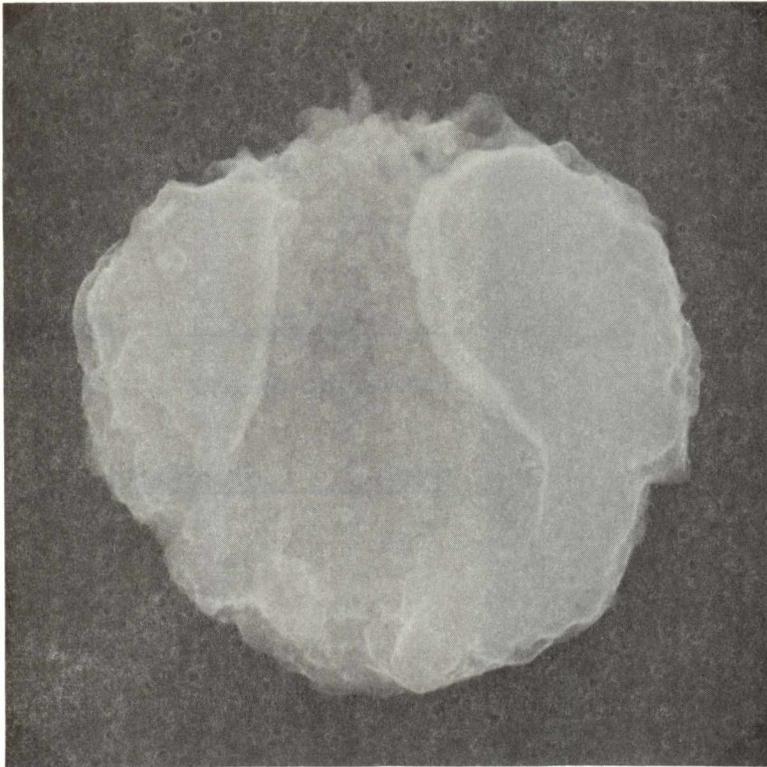


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
18	S	O
<u>COLOR</u>		<u>LUSTER</u>
Black		V
<u>TYPE</u>	<u>COMMENTS</u>	
TCA		

S-85-36028

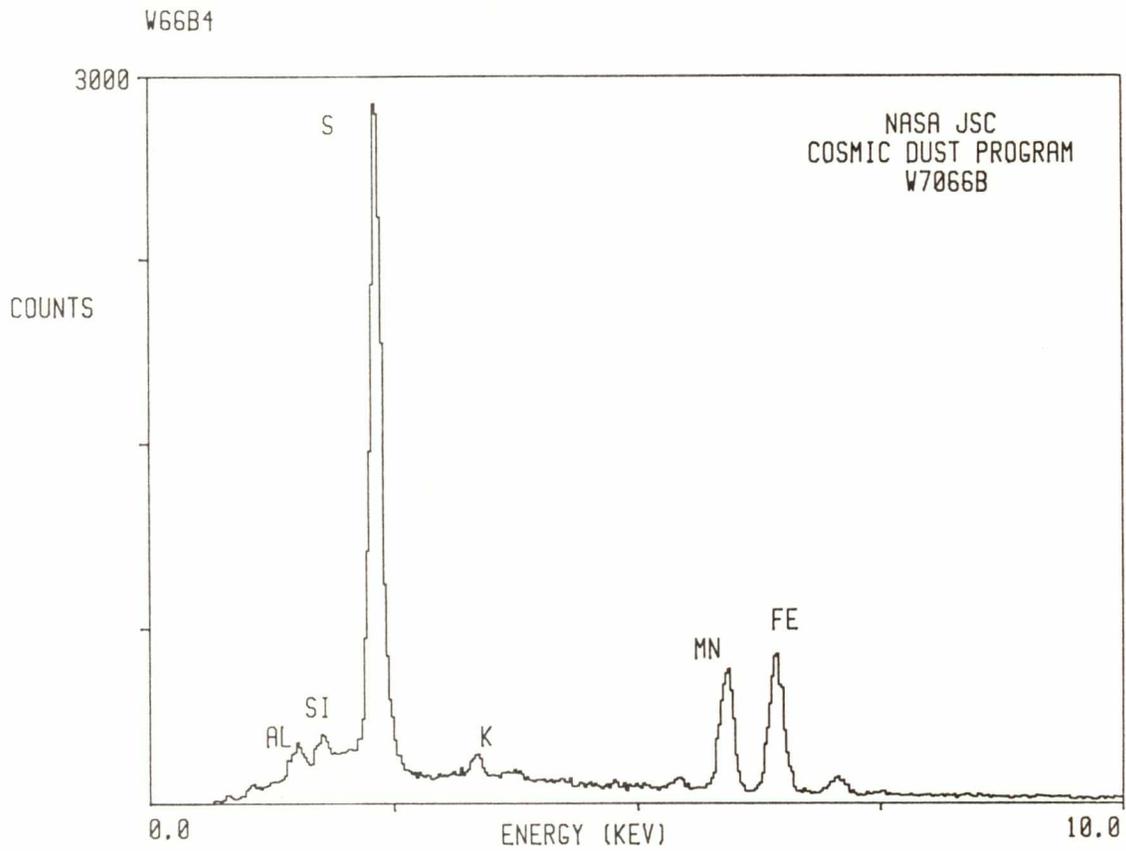


W7066B4

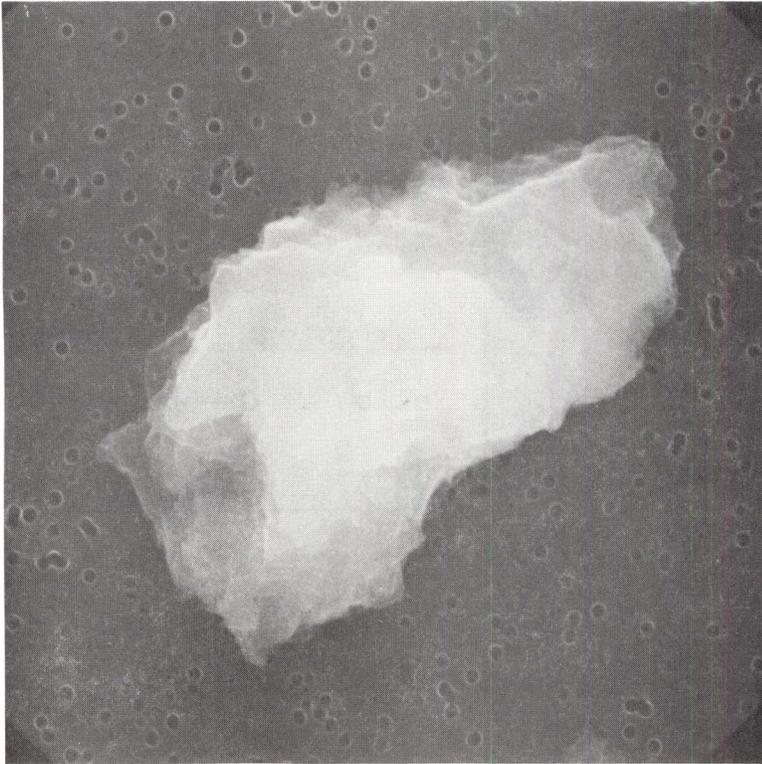


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
10	S	O
<u>COLOR</u>		<u>LUSTER</u>
Yellow to Green		SM/SV
<u>TYPE</u>	<u>COMMENTS</u>	
TCA		

S-85-36029

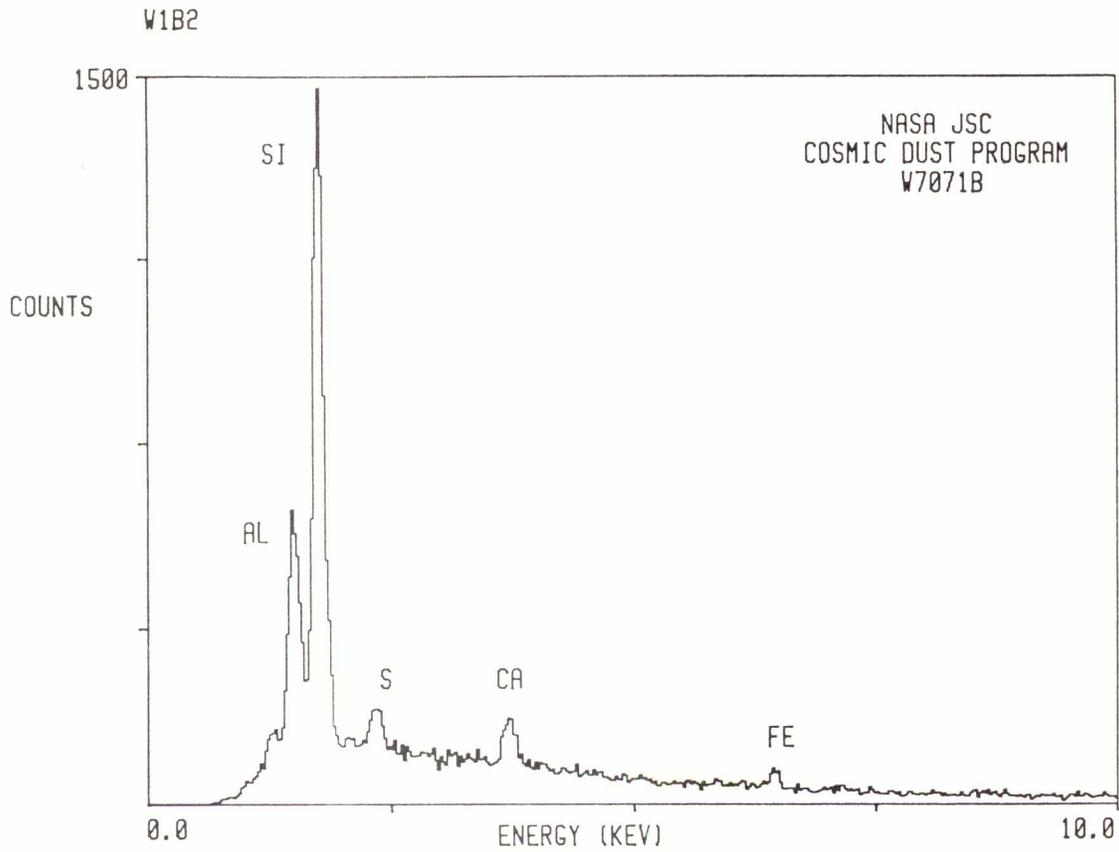


W7071B2

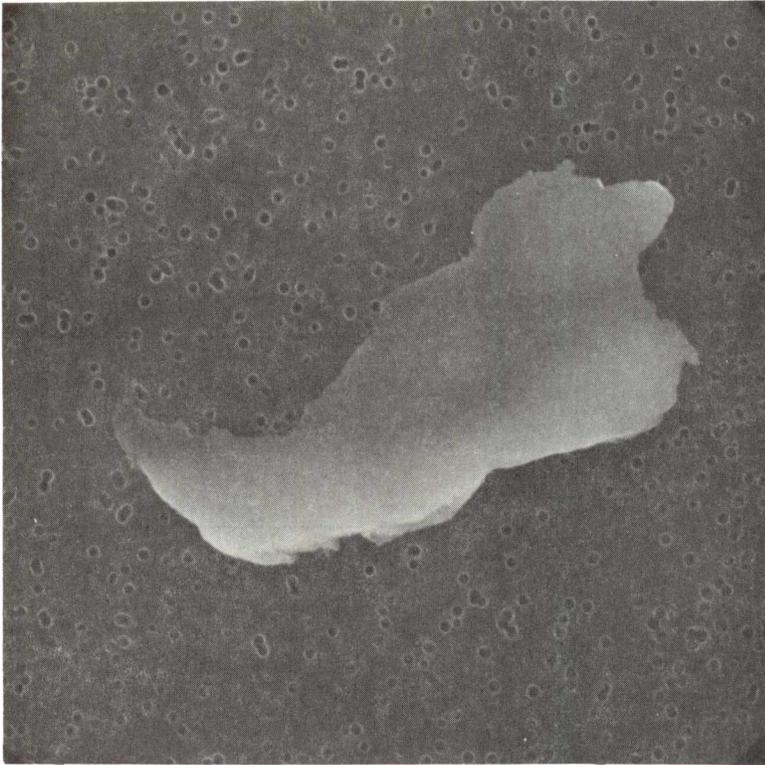


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
16x10	I	O
<u>COLOR</u>		<u>LUSTER</u>
Brown to Black		SV/D
<u>TYPE</u>	<u>COMMENTS</u>	
TCN		

S-85-36050



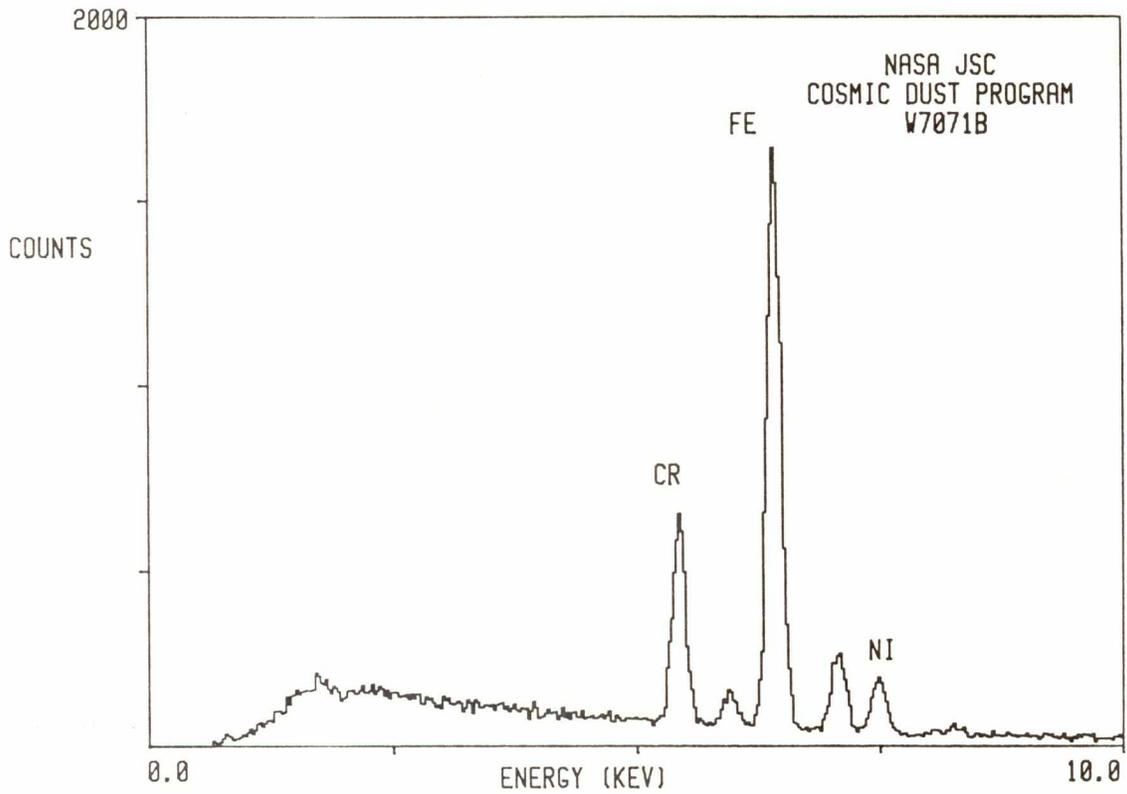
W7071B3



<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
20x9	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black		SM
<u>TYPE</u>	<u>COMMENTS</u>	
TCA		

S-85-36051

W1B3



U2018A1



SIZE SHAPE TRANS.

35x20 S/I O

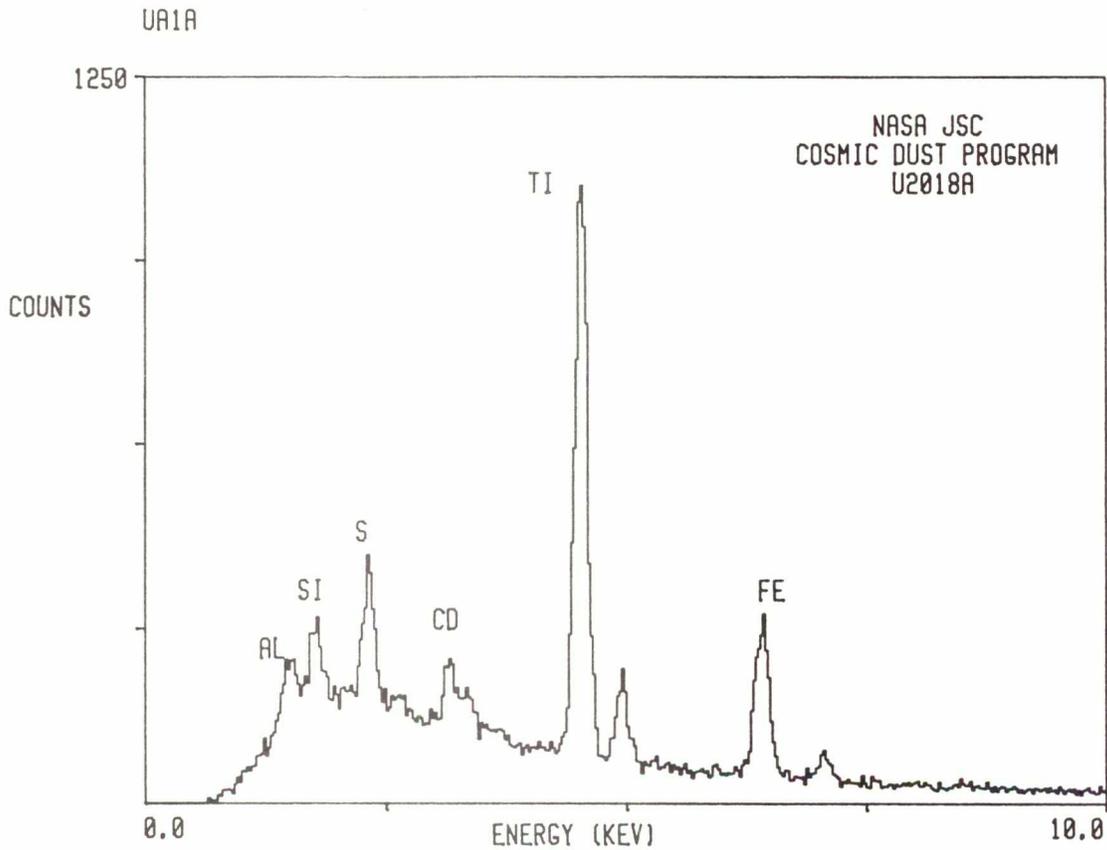
COLOR LUSTER

White, Yellow
and Black SV/D

TYPE COMMENTS

TCN Associated with
U2018A2

S-85-36016



U2018A2

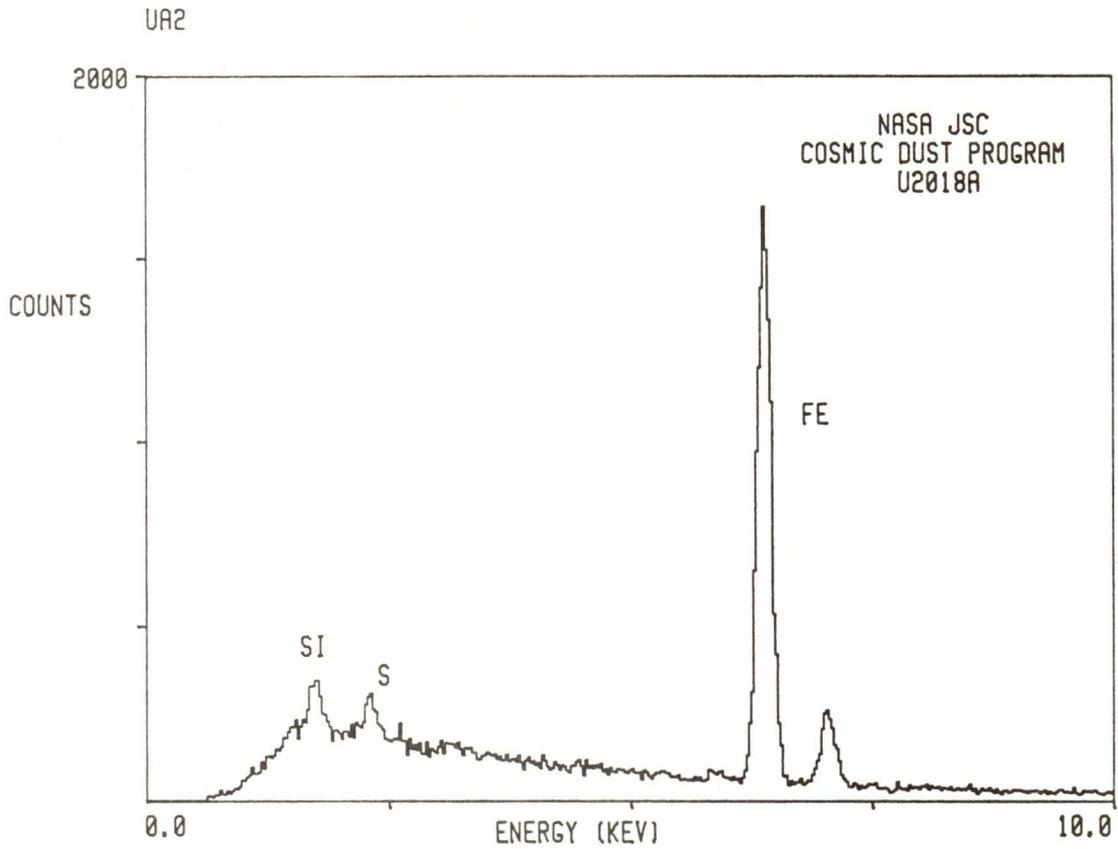


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
13x7	I	O

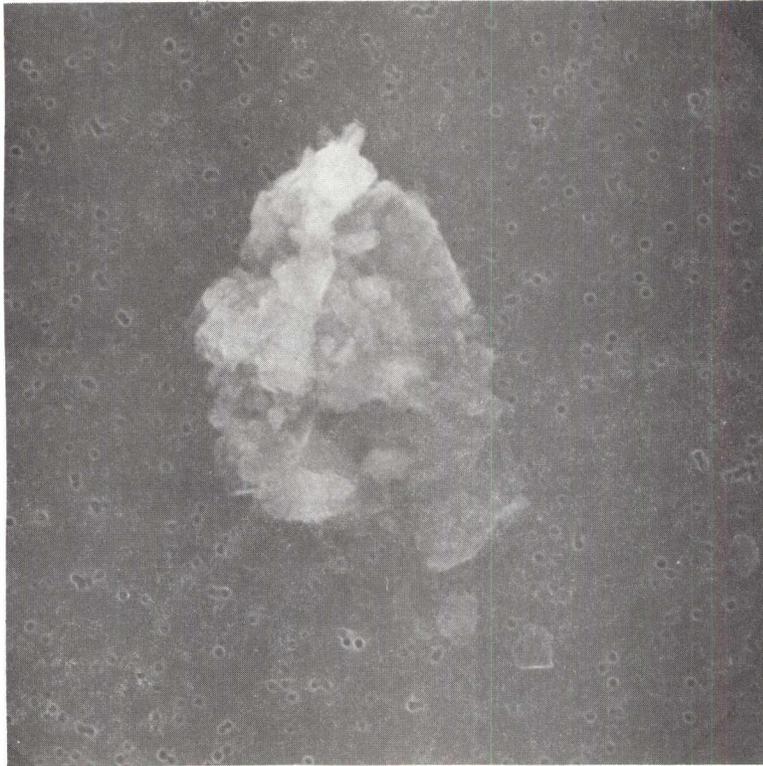
<u>COLOR</u>	<u>LUSTER</u>
Yellow	SV

<u>TYPE</u>	<u>COMMENTS</u>
TCN	Associated with U2018A1; smaller particles also present

S-85-36017

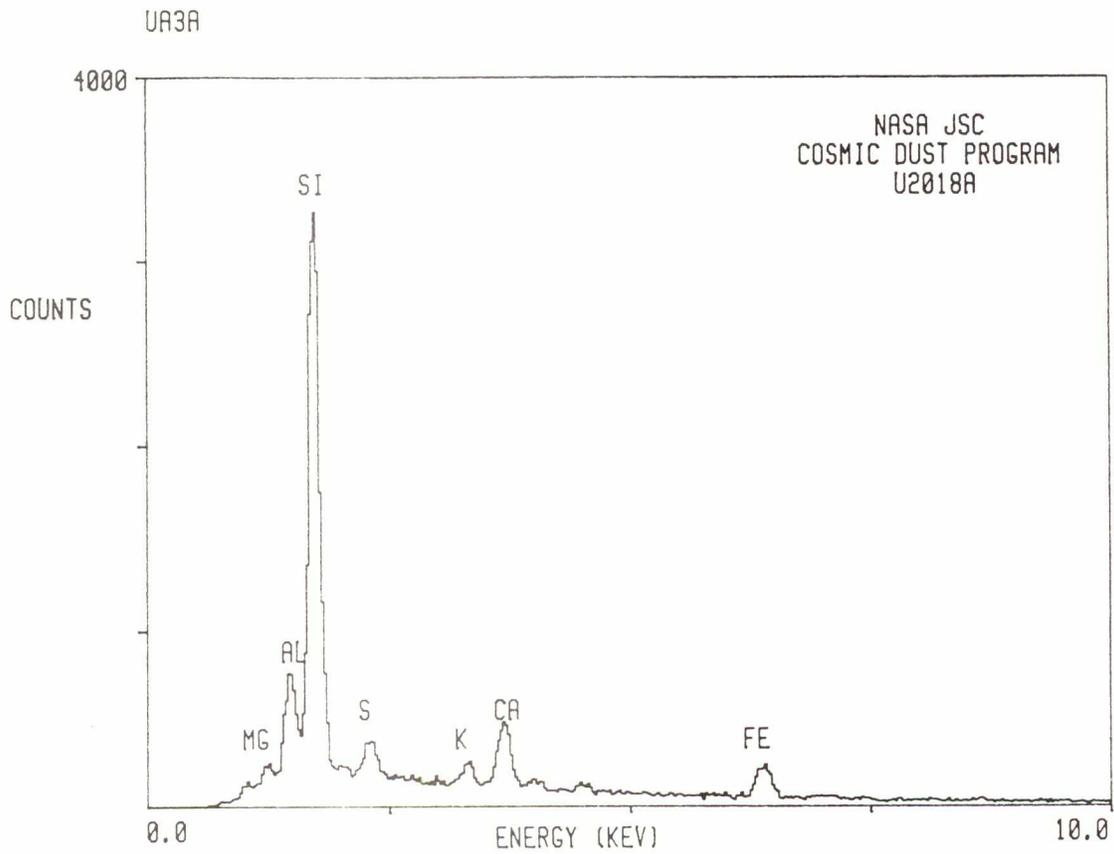


U2018A3



<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
15	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black		SM/D
<u>TYPE</u>	<u>COMMENTS</u>	
TCN		

S-85-36018

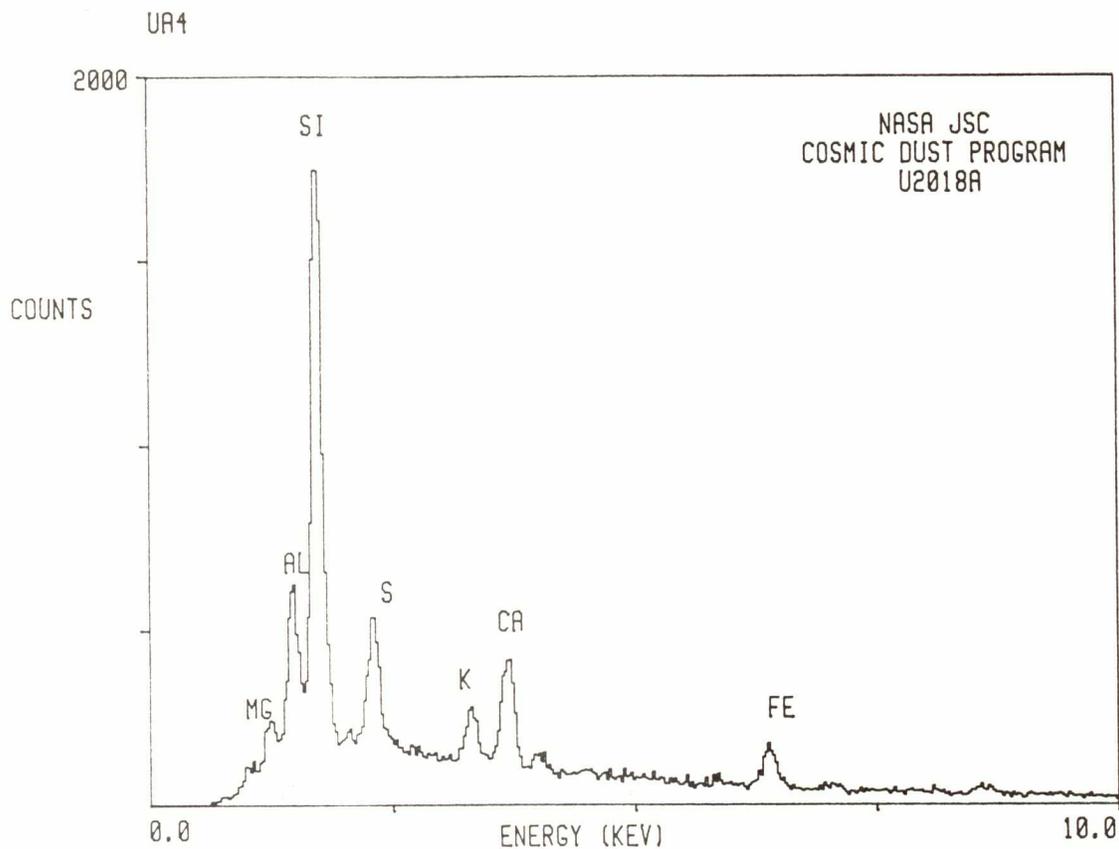


U2018A4

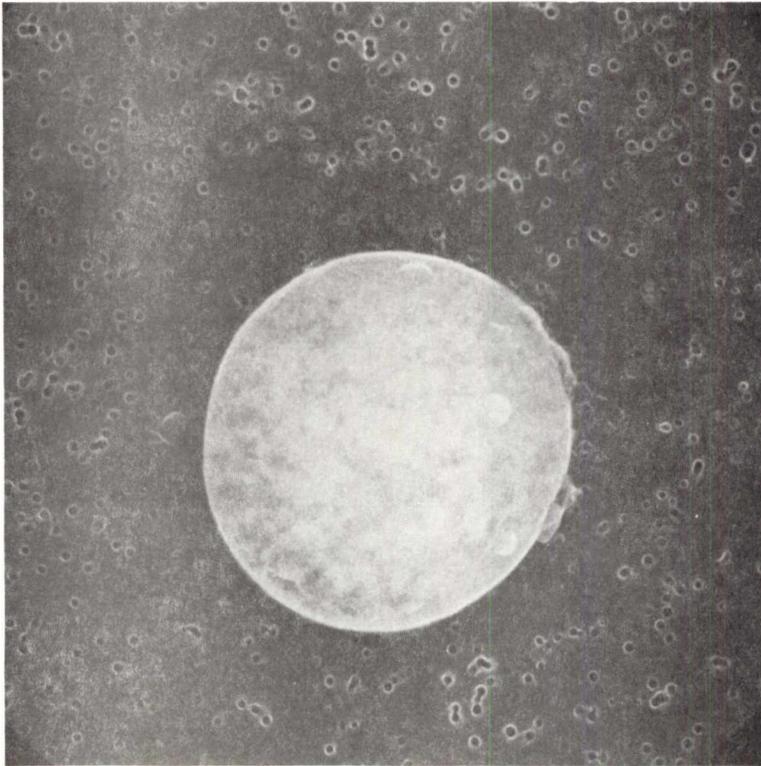


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
26x13	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black		SV/D
<u>TYPE</u>	<u>COMMENTS</u>	
	TCN Reacted with Hexane during washing	

S-85-36019

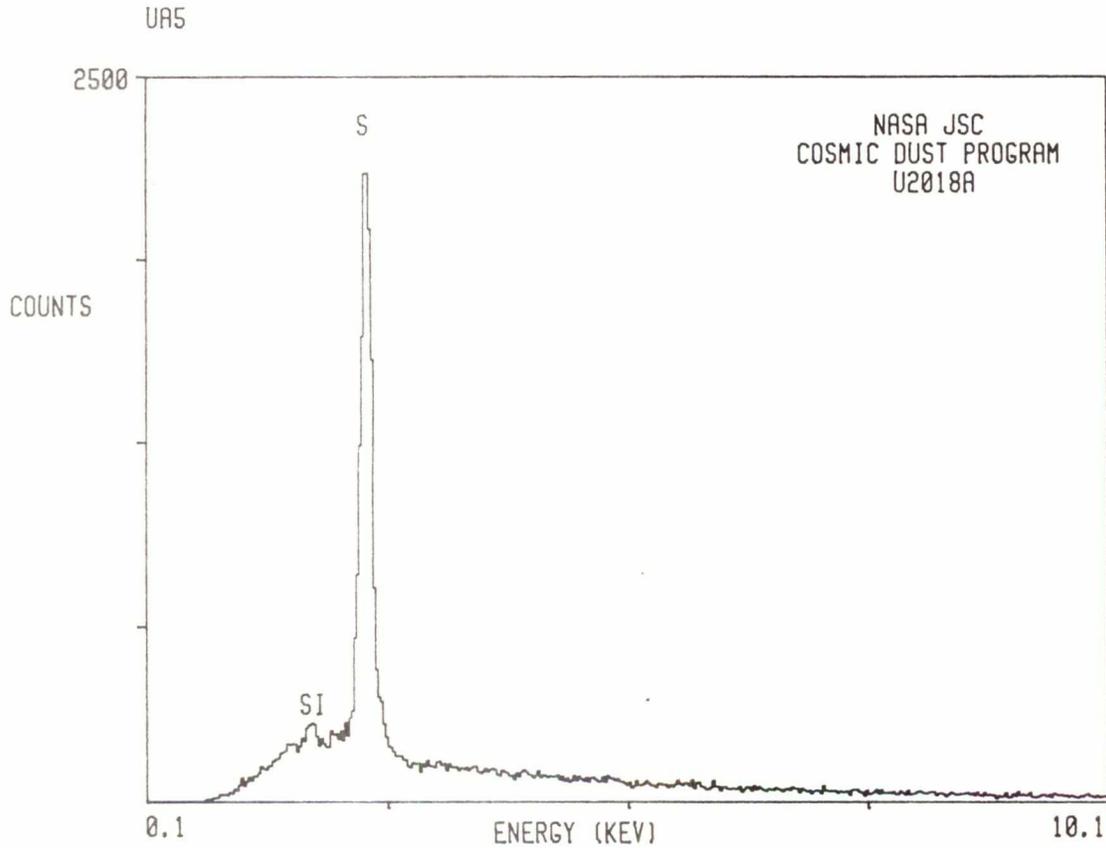


U2018A5

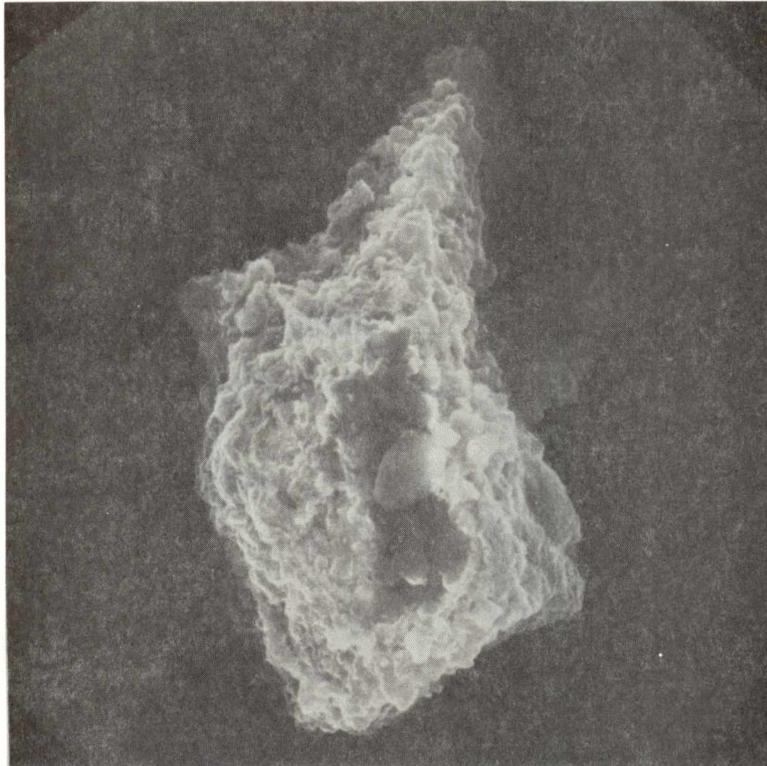


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
15	S	TL
<u>COLOR</u>		<u>LUSTER</u>
Amber		V
<u>TYPE</u>	<u>COMMENTS</u>	
TCN		

S-85-36020



U2018A6



SIZE SHAPE TRANS.

70x65 I O

COLOR LUSTER

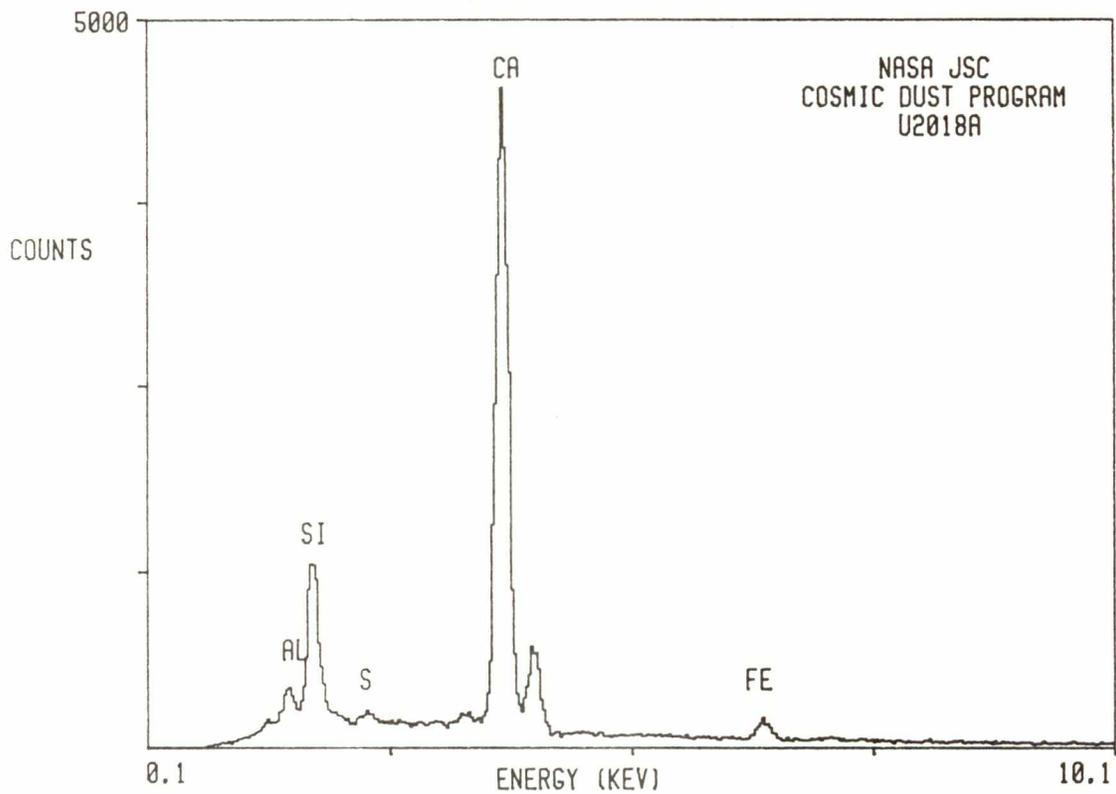
White, Yellow
and Black SV/D

TYPE COMMENTS

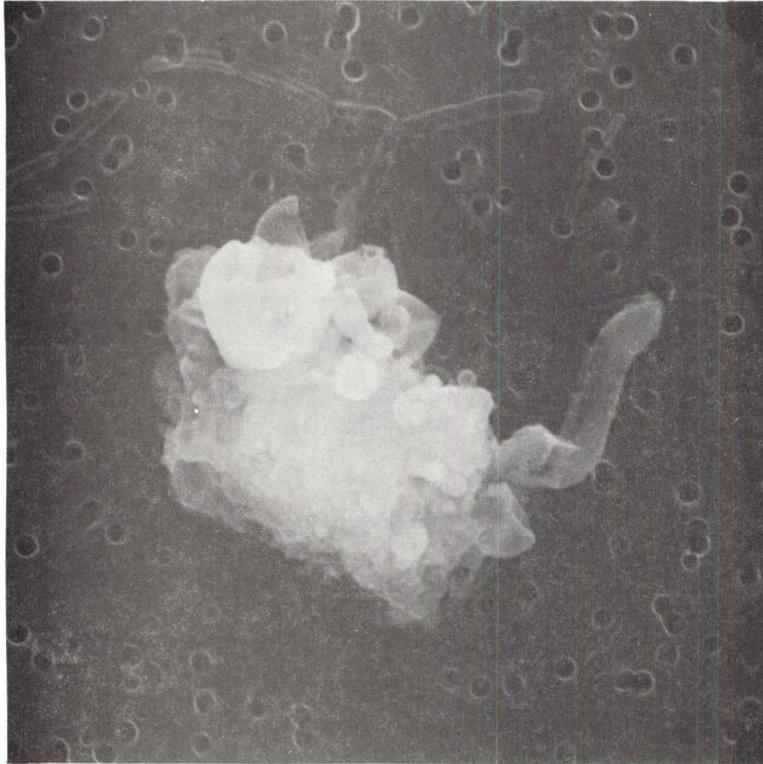
TCN Similar to U2018A1
and A2

S-85-36021

UA6

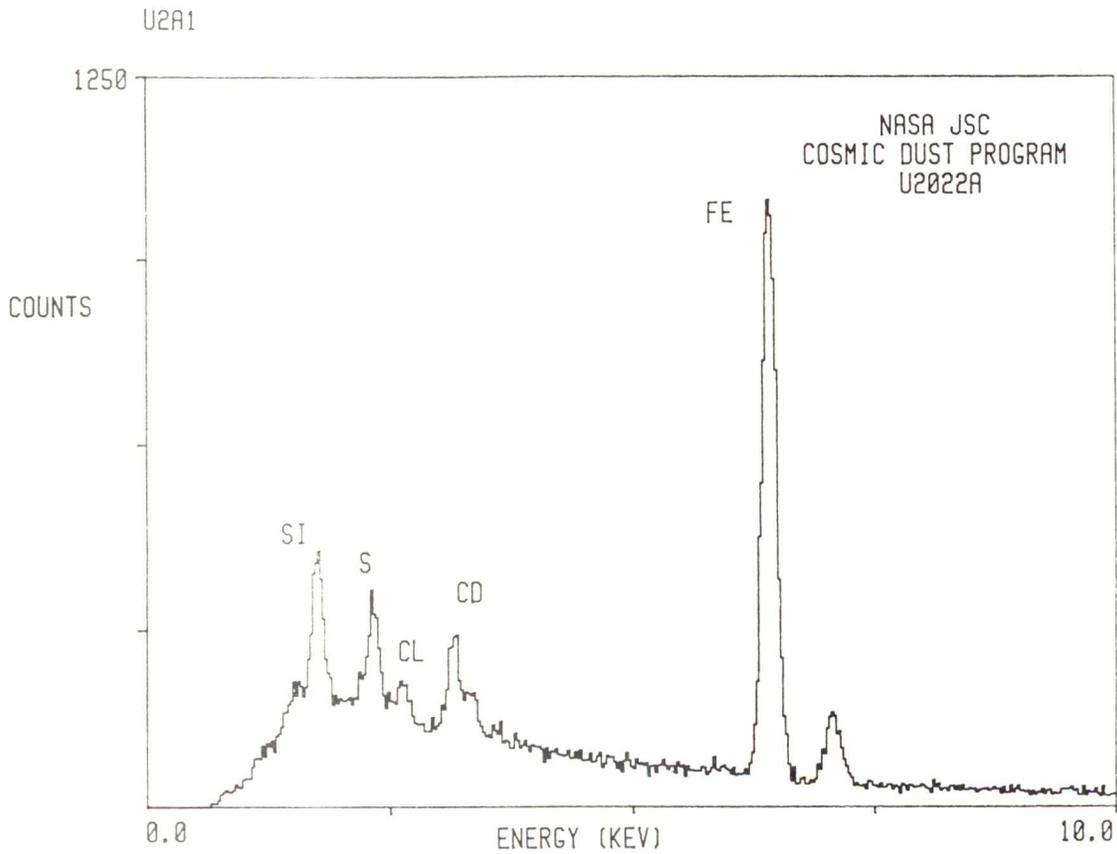


U2022A1

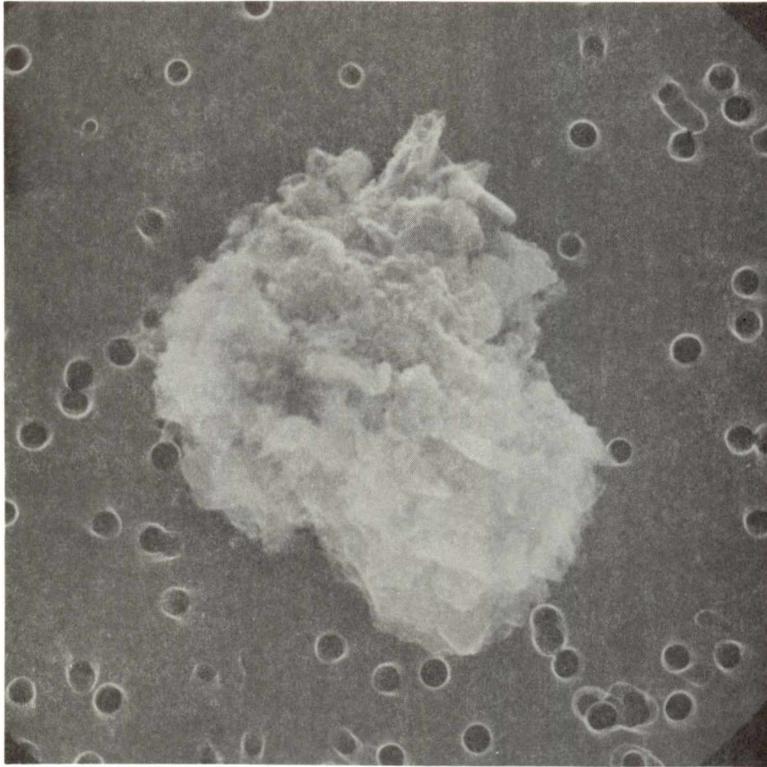


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
7	I	O
<u>COLOR</u>		<u>LUSTER</u>
Gold to Brown		SM/D
<u>TYPE</u>	<u>COMMENTS</u>	
TCA		

S-85-36011

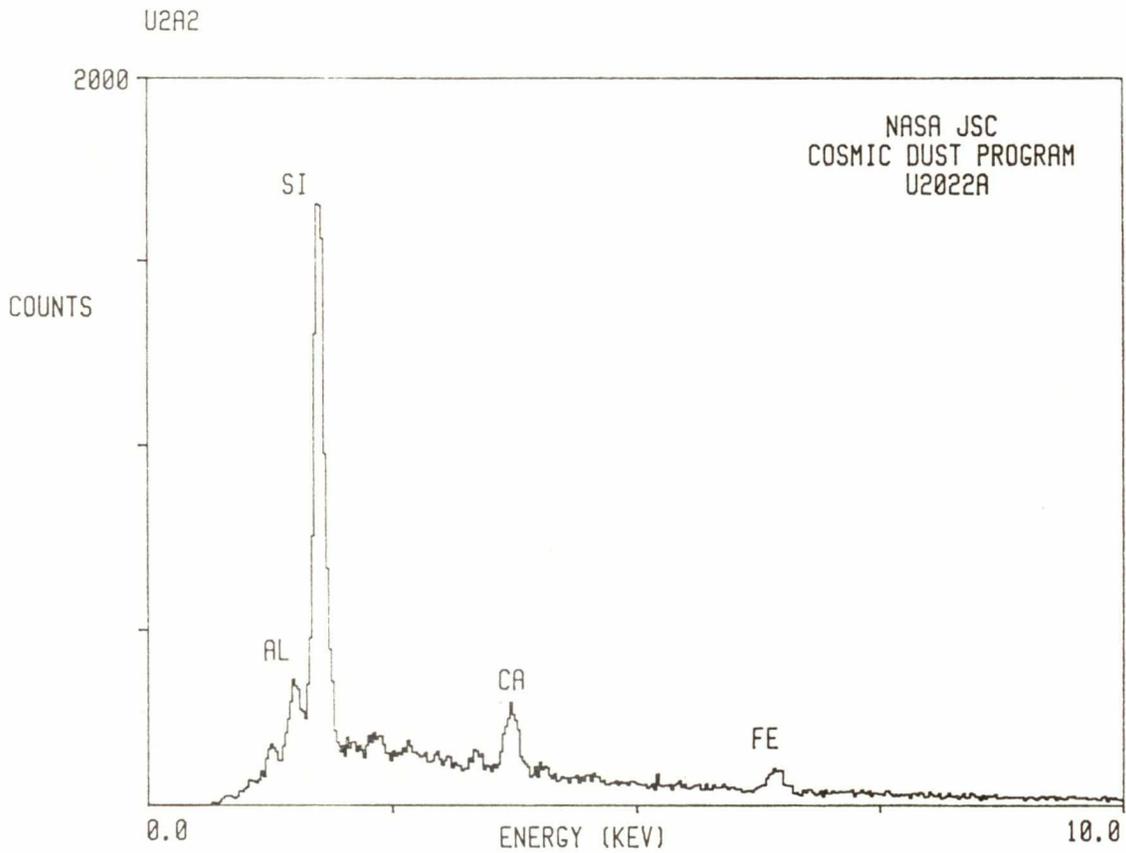


U2022A2

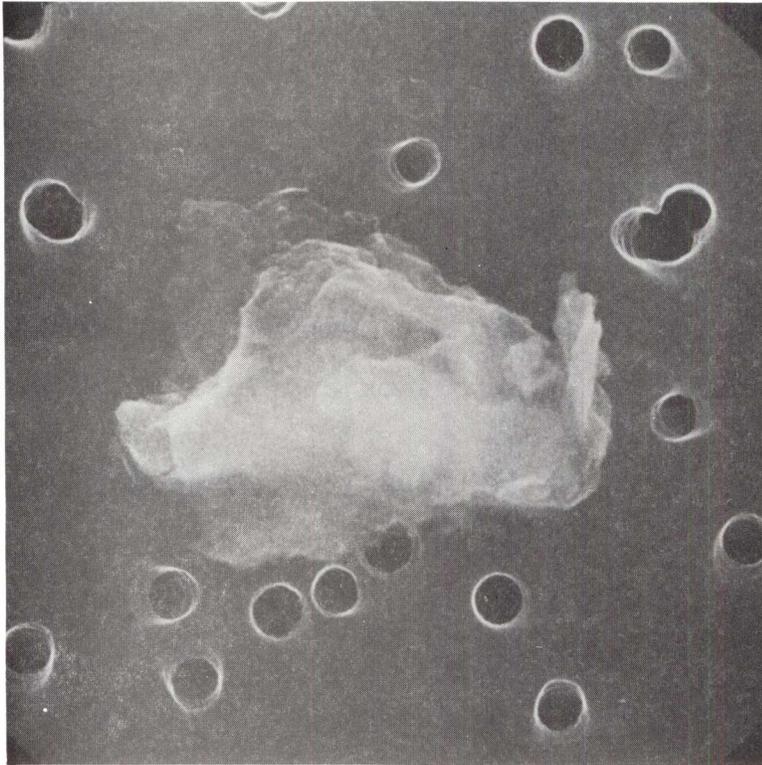


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
8	I	O
<u>COLOR</u>		<u>LUSTER</u>
Black and Gold		SM/D
<u>TYPE</u>	<u>COMMENTS</u>	
TCN		

S-85-36012

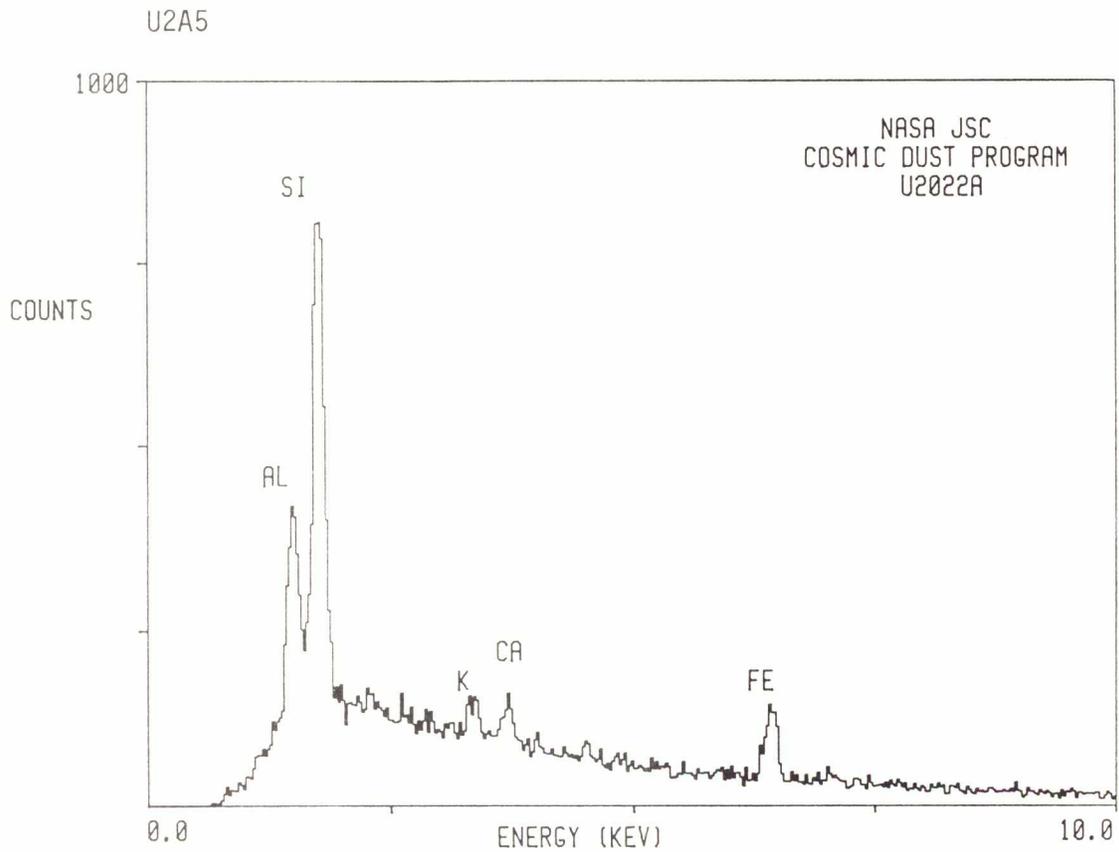


U2022A5



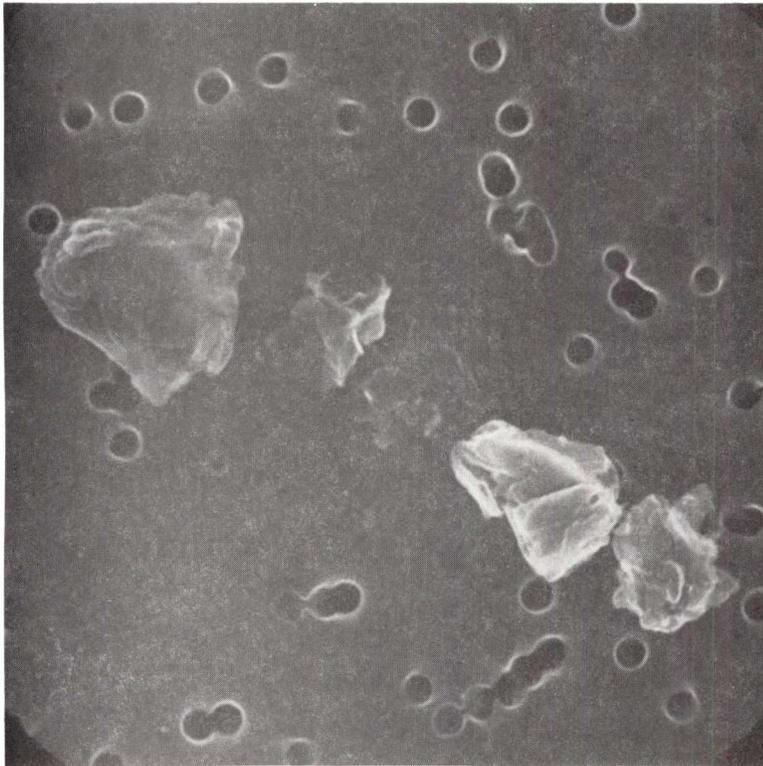
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
45x25	I	O
<u>COLOR</u>		<u>LUSTER</u>
Yellow, Orange and White		SV
<u>TYPE</u>	<u>COMMENTS</u>	
TCN		

S-85-35015



UNCERTAIN

W7010C3



SIZE SHAPE TRANS.

Largest grain

5x3

I

O

COLOR

LUSTER

Black

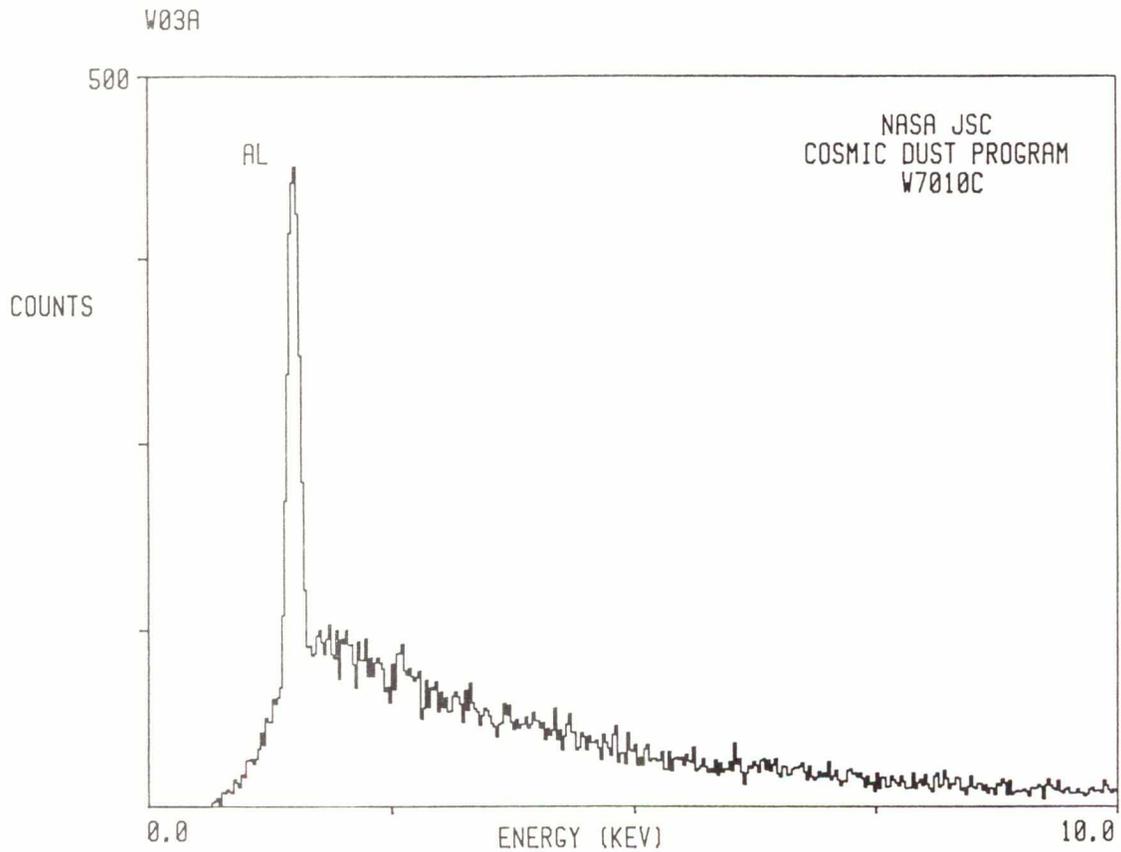
D

TYPE

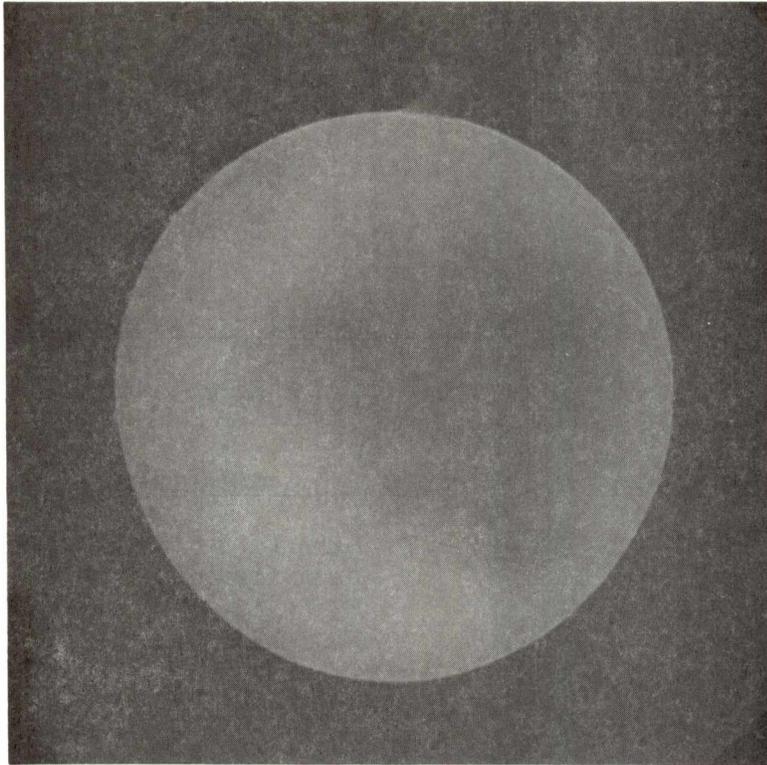
COMMENTS

? Sample of W7010*A,
train of several
pieces

S-85-35024



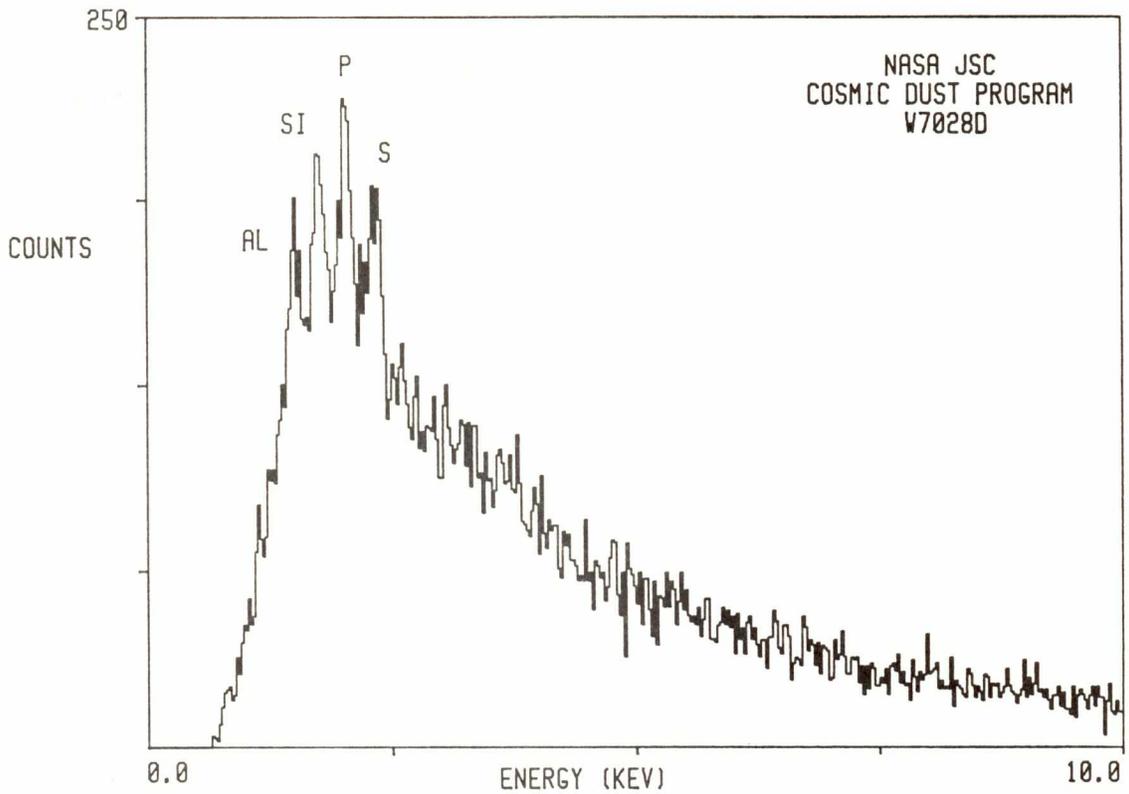
W7028D3



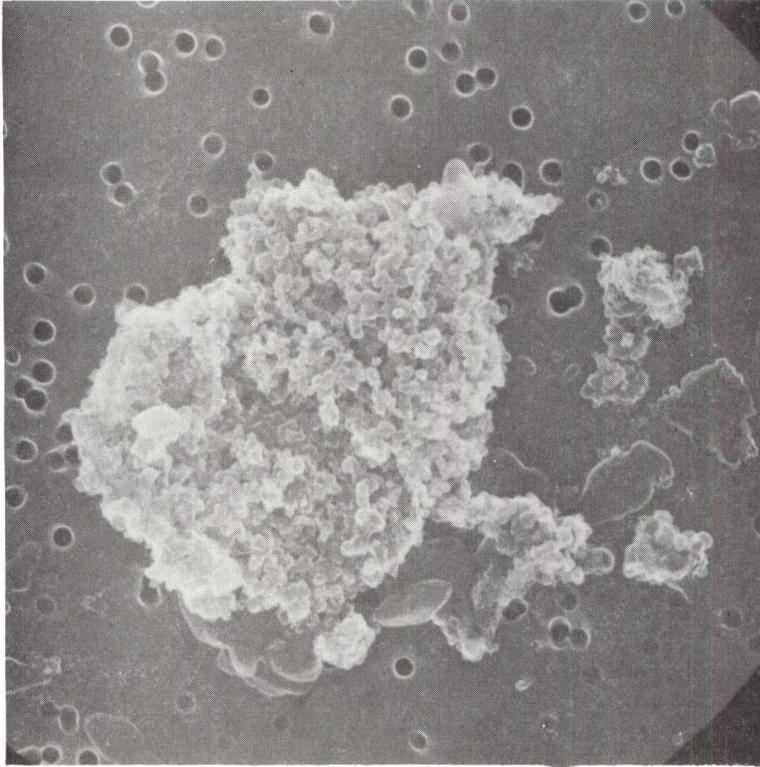
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
21	S	O
<u>COLOR</u>		<u>LUSTER</u>
Black		V
<u>TYPE</u>	<u>COMMENTS</u>	
?		

S-85-36004

W803



W7031E5



SIZE SHAPE TRANS.

11x4 I O

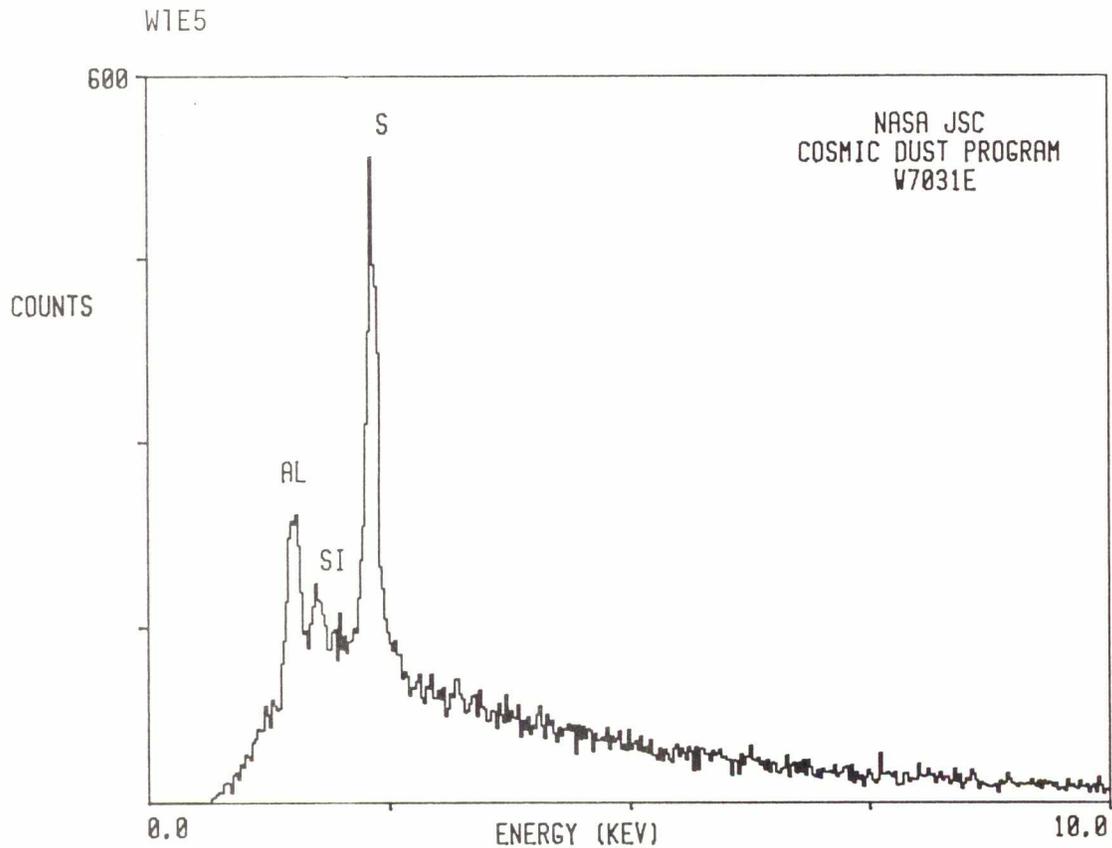
_____ COLOR _____ LUSTER

Yellow to Black SV/D

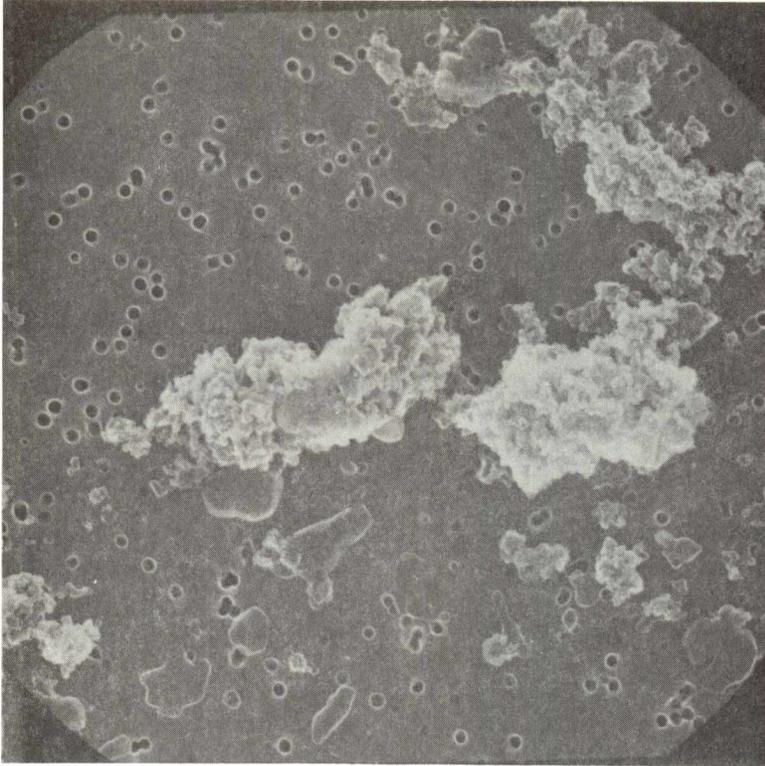
TYPE _____ COMMENTS

? Sample of W7031*D;
associated with
W7031A9 and
W7031E6

S-85-35997



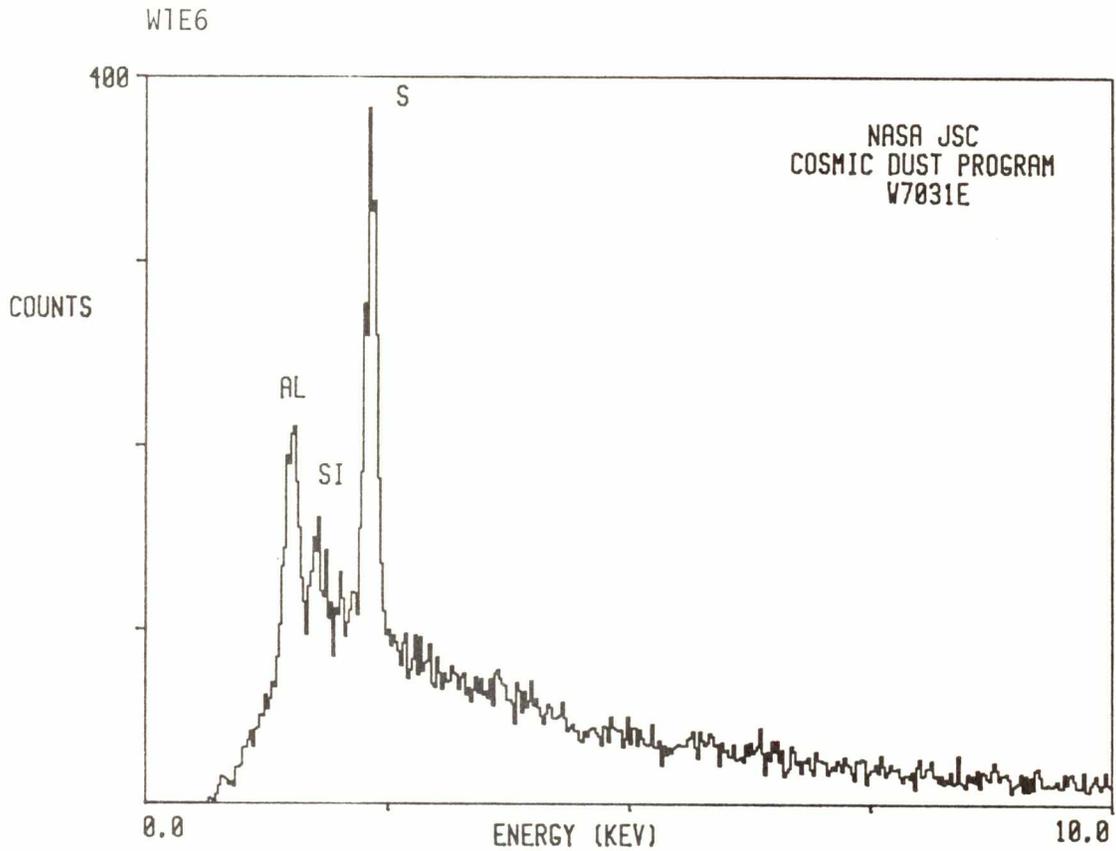
W7031E6



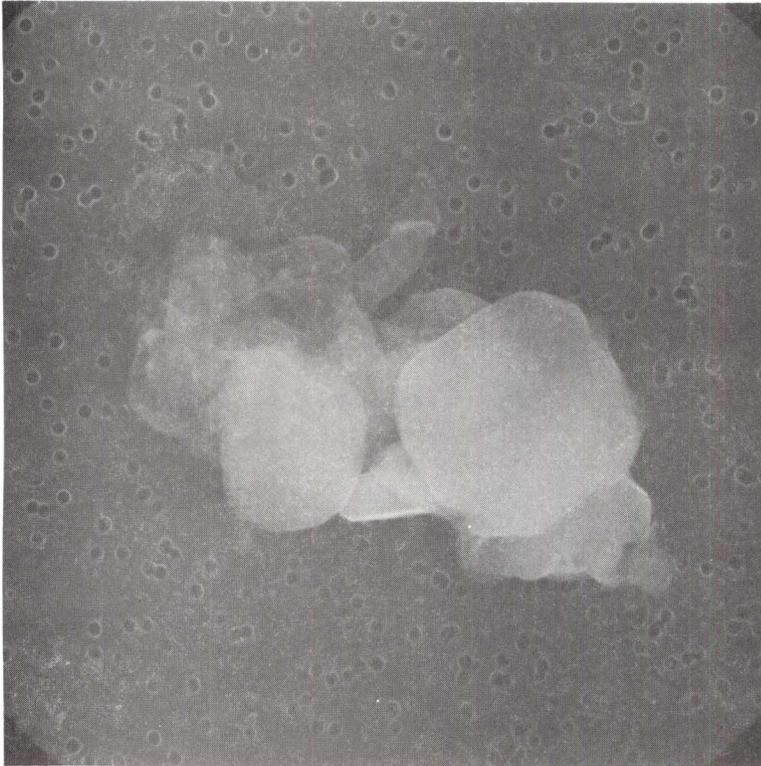
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
8x5	I	O
<u>COLOR</u>		<u>LUSTER</u>
Yellow to Black		SV/D

<u>TYPE</u>	<u>COMMENTS</u>
?	Two grains, sample of W7031*D; associated with W7031A9 and W7031E5

S-85-35998



W7071B1



SIZE SHAPE TRANS.

15x10 I O

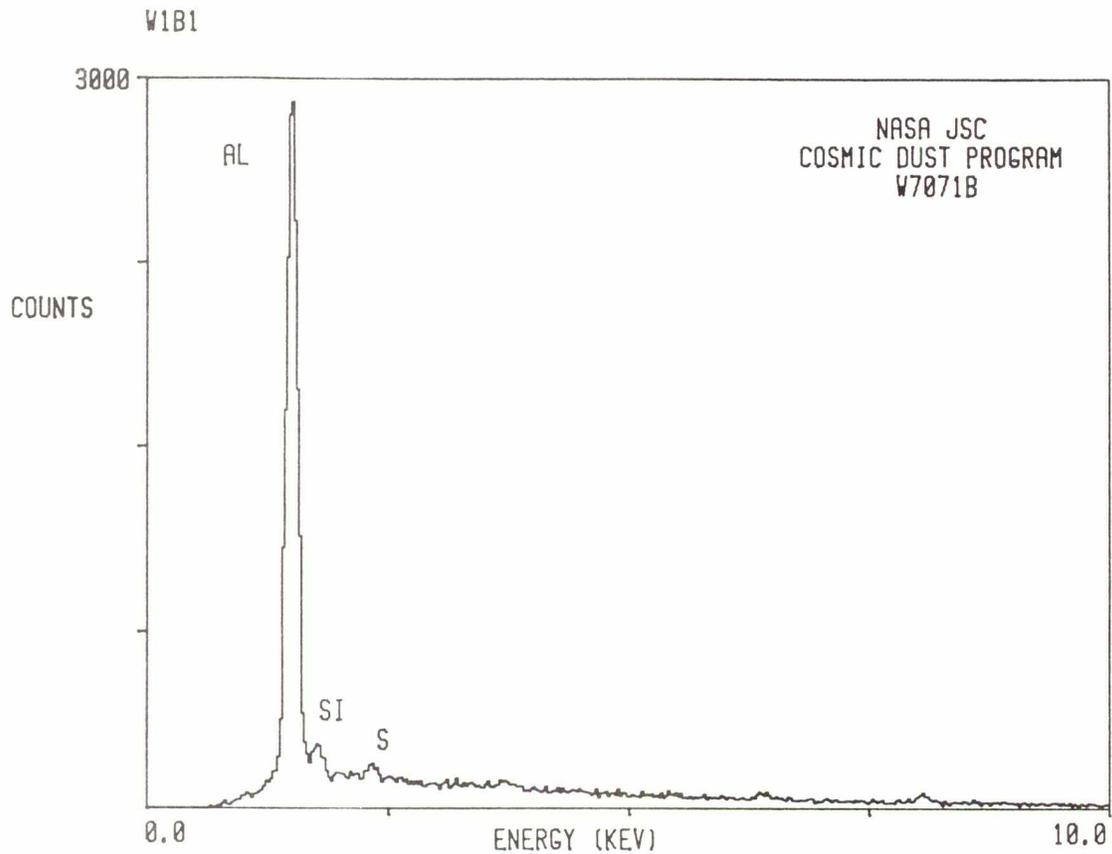
_____ COLOR _____ LUSTER

Bronze to Brown M/D

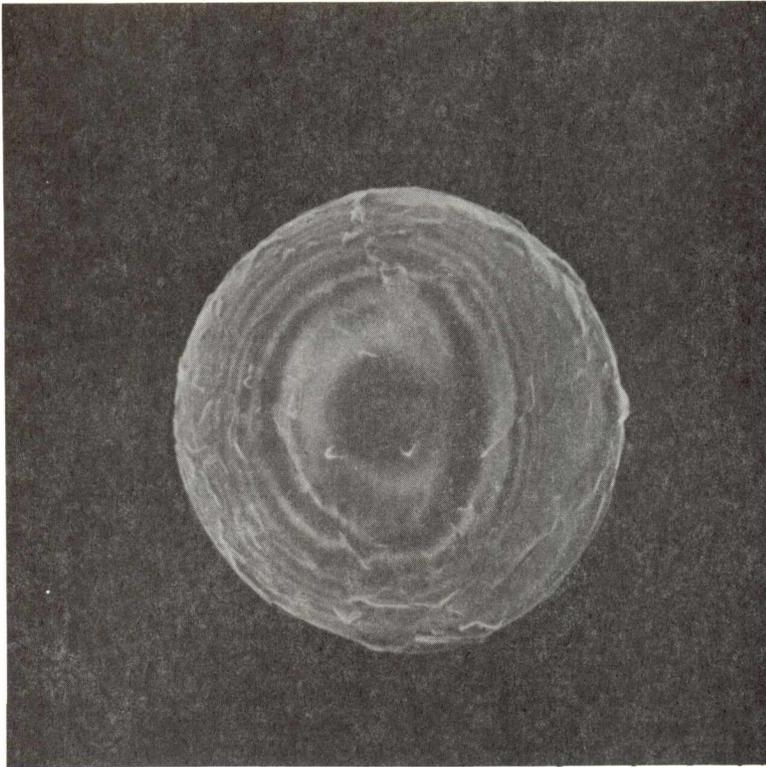
TYPE _____ COMMENTS

? Sample of W7071*A;
associated with
W7071A1 and A2

S-85-36049

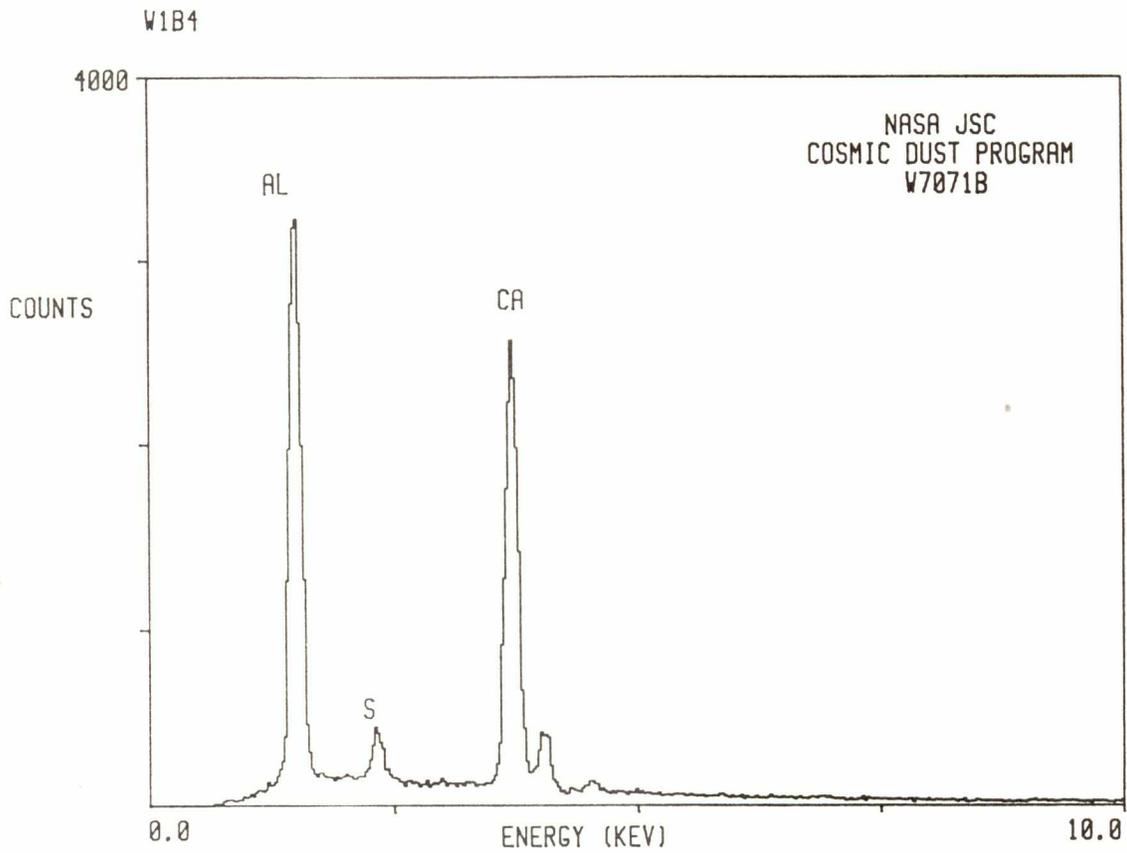


W7071B4

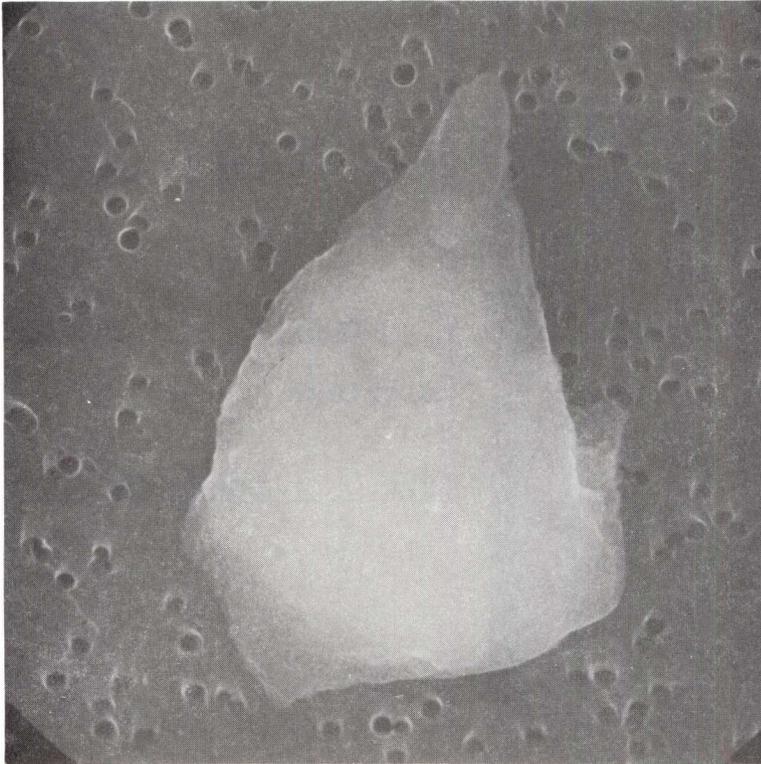


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
27	S	T
<u>COLOR</u>		<u>LUSTER</u>
Colorless		V
<u>TYPE</u>	<u>COMMENTS</u>	
?		

S-85-36052

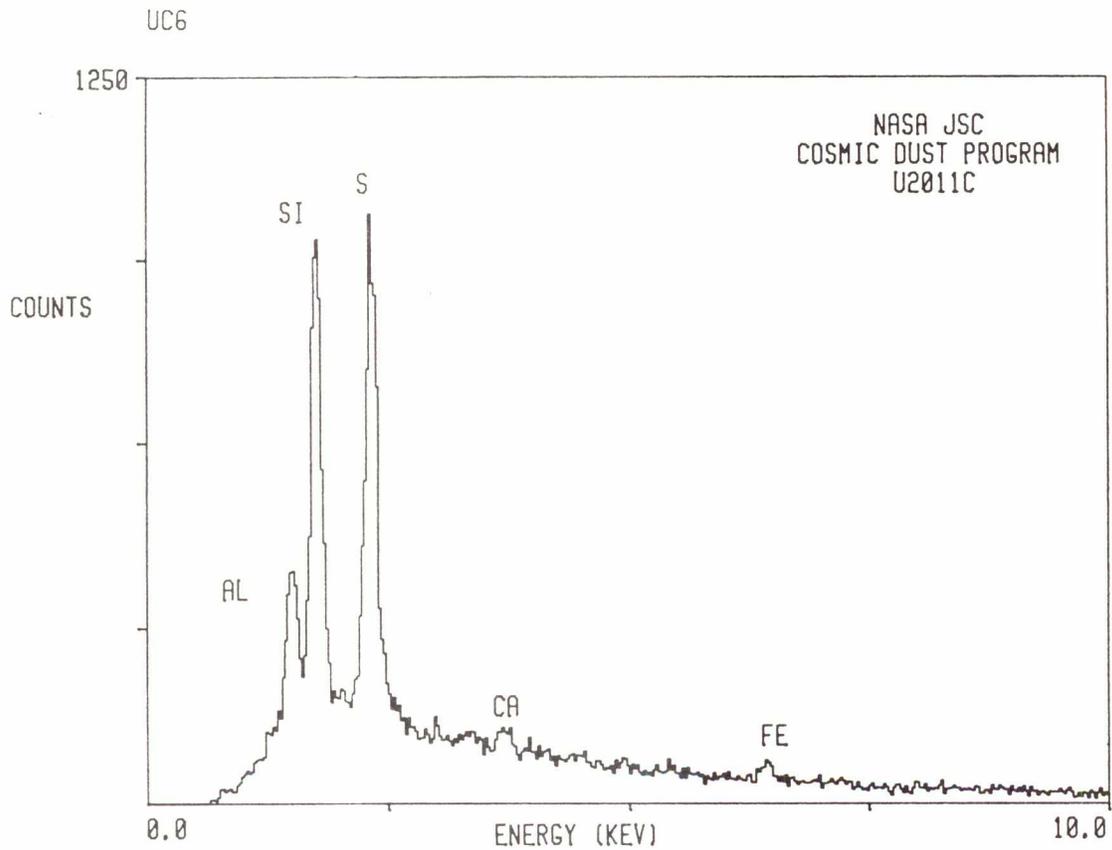


U2011C6

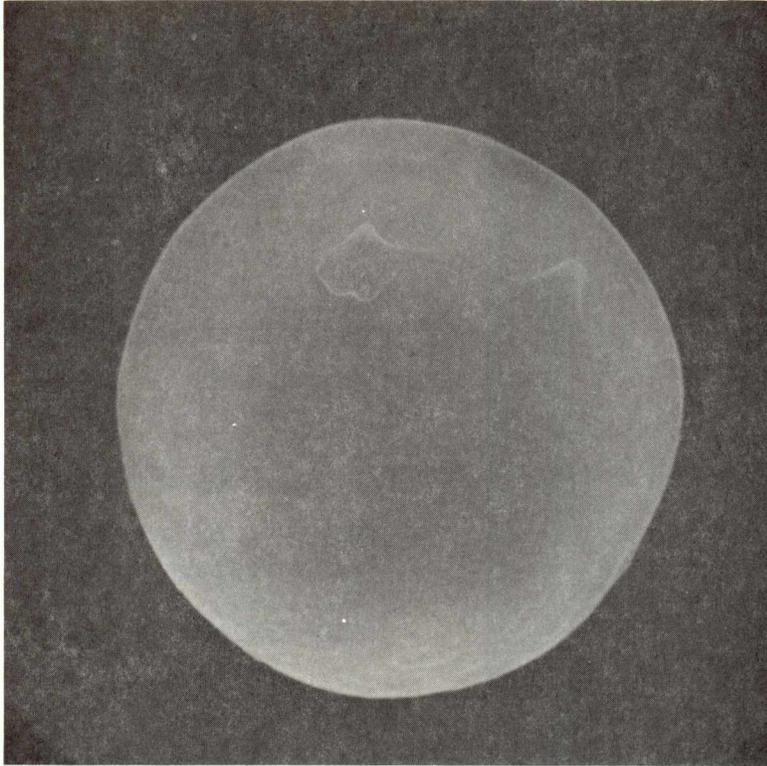


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
12x9	I	O
<u>COLOR</u>		<u>LUSTER</u>
Bronze to Black		SM/V
<u>TYPE</u>	<u>COMMENTS</u>	
?		

S-85-36035

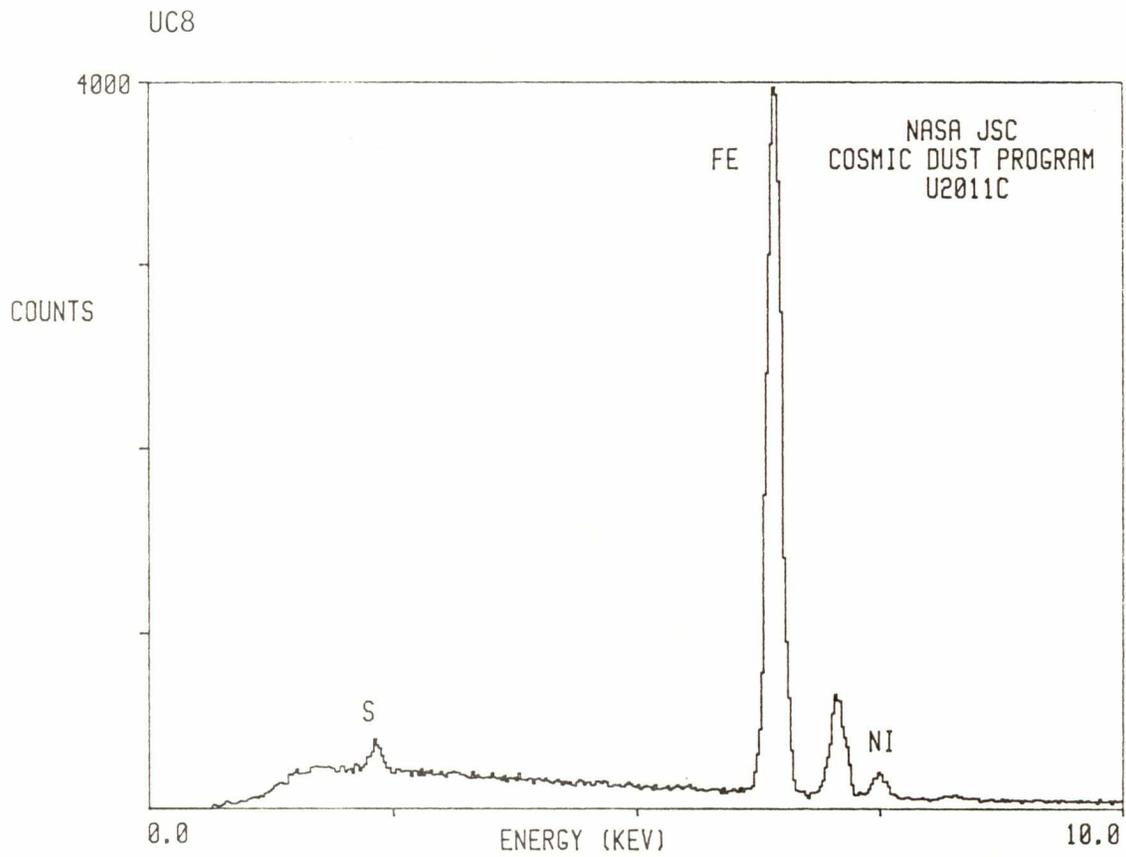


U2011C8

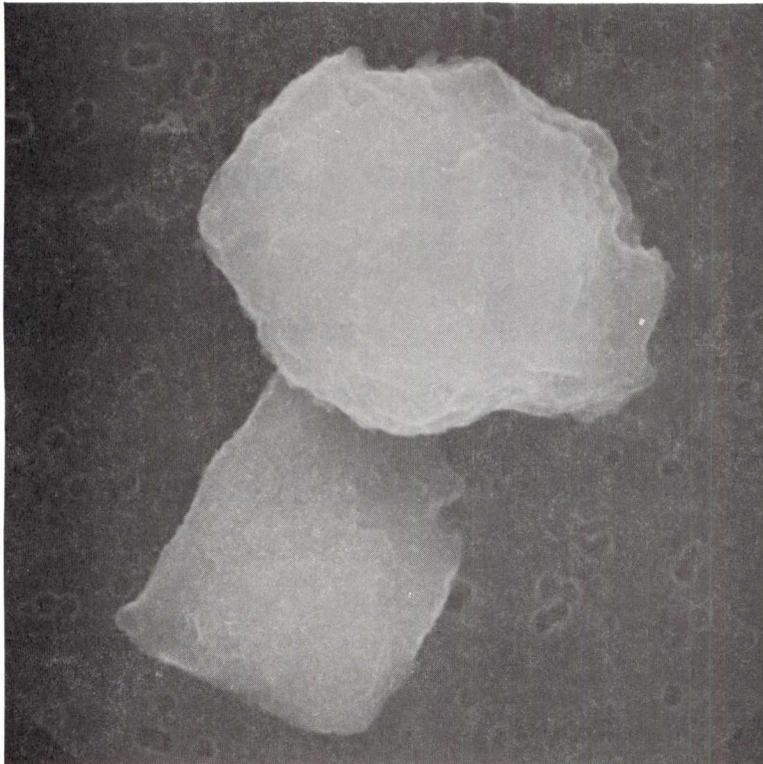


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
12	S	O
<u>COLOR</u>		<u>LUSTER</u>
Dk. Brown		V
<u>TYPE</u>	<u>COMMENTS</u>	
?		

S-85-36037



U2015G2



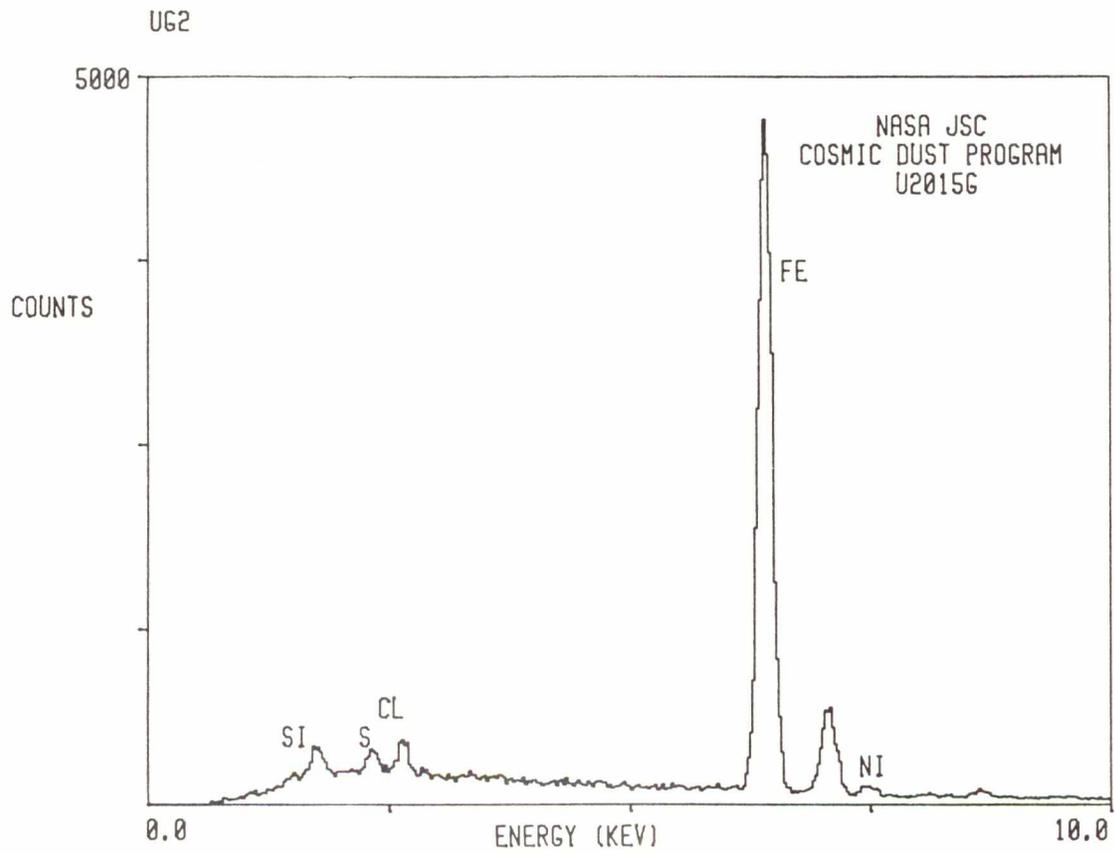
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
10x8	I	O/TL

<u>COLOR</u>	<u>LUSTER</u>
Gold to Black	SV/D

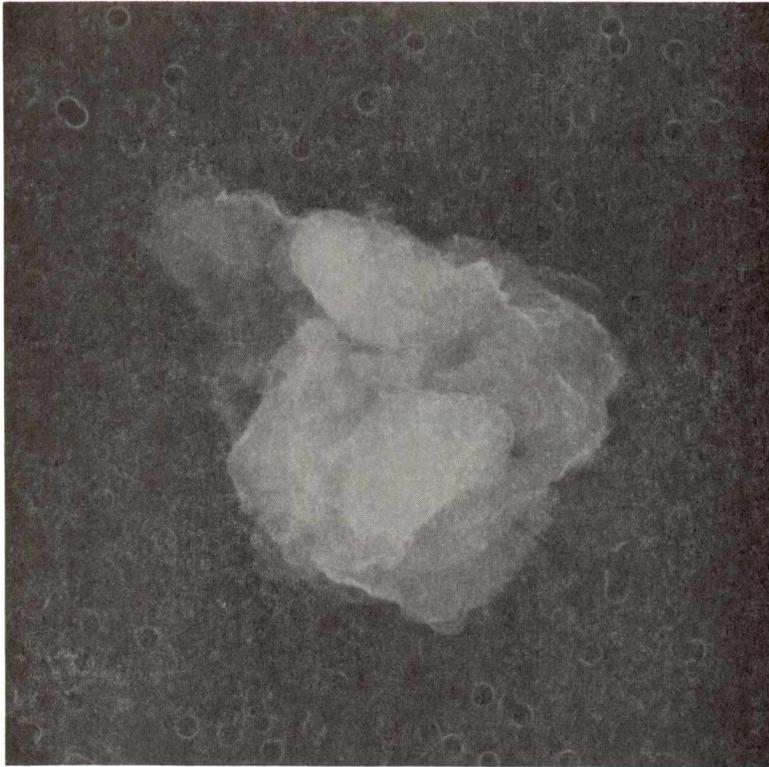
<u>TYPE</u>	<u>COMMENTS</u>
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?	Sample of U2015*A; associated with U2015G1, U2015B1-4,6
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S-85-35991



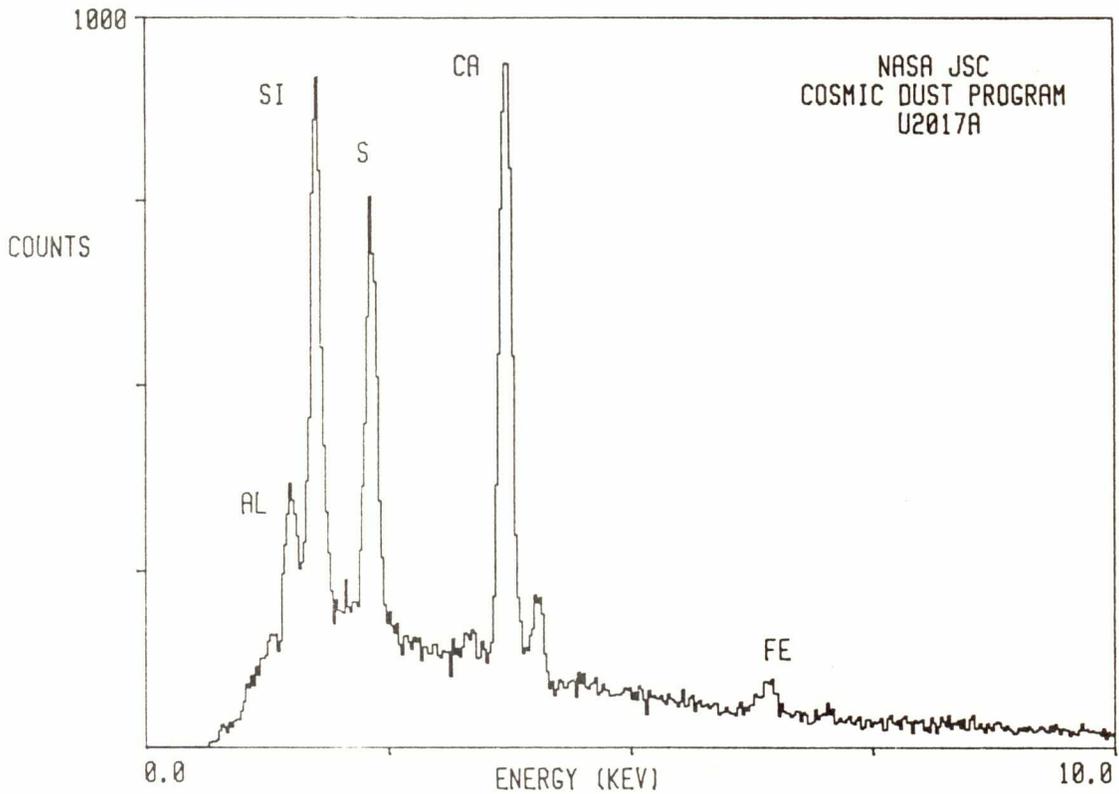
U2017A3



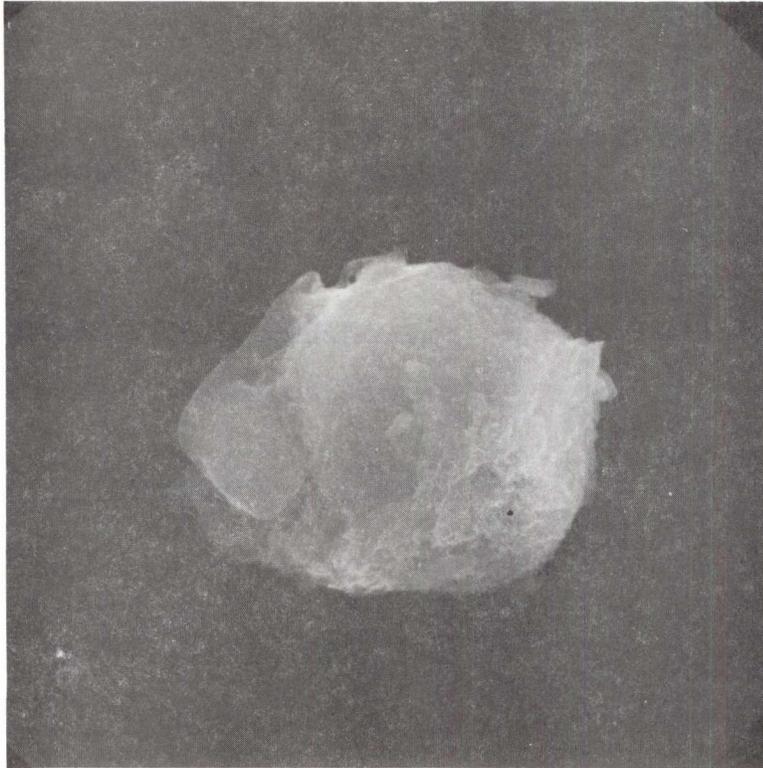
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
11	I	O
<u>COLOR</u>		<u>LUSTER</u>
Bronze to Black		SM/M
<u>TYPE</u>	<u>COMMENTS</u>	
?		

S-85-36040

U7A3



U2017A6

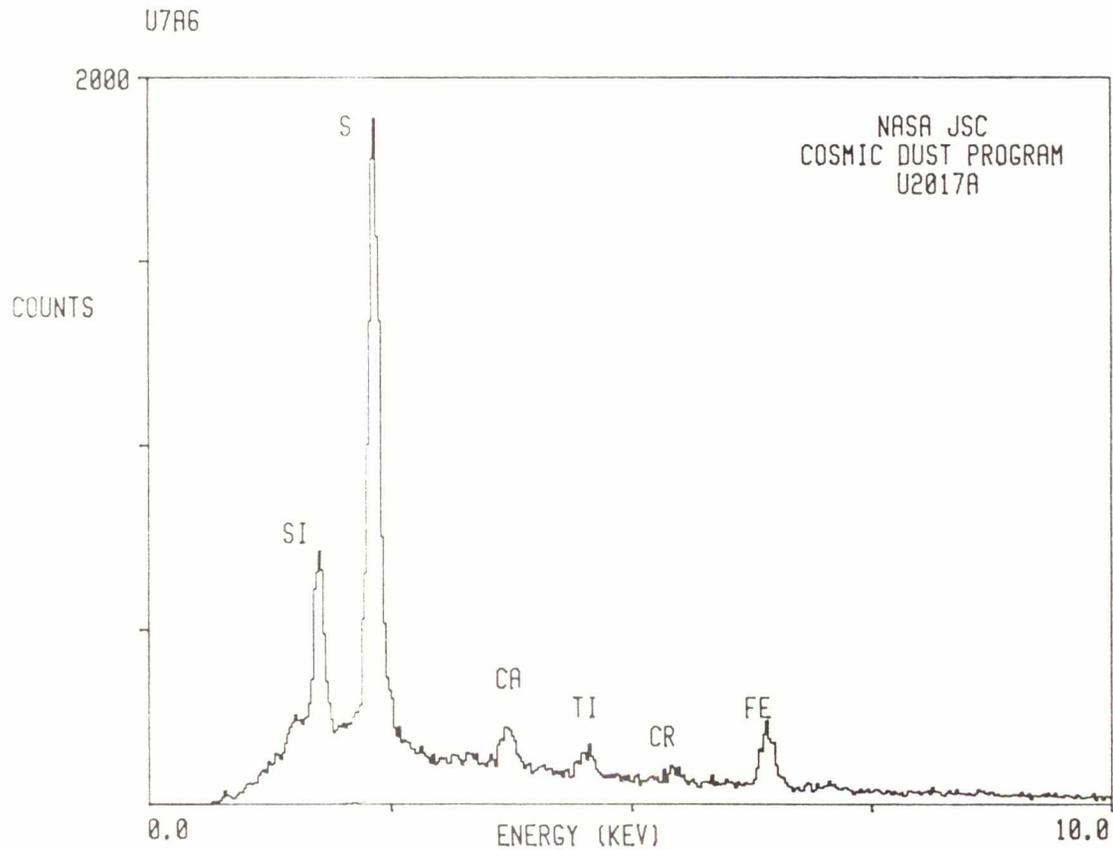


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
40	S	O/T

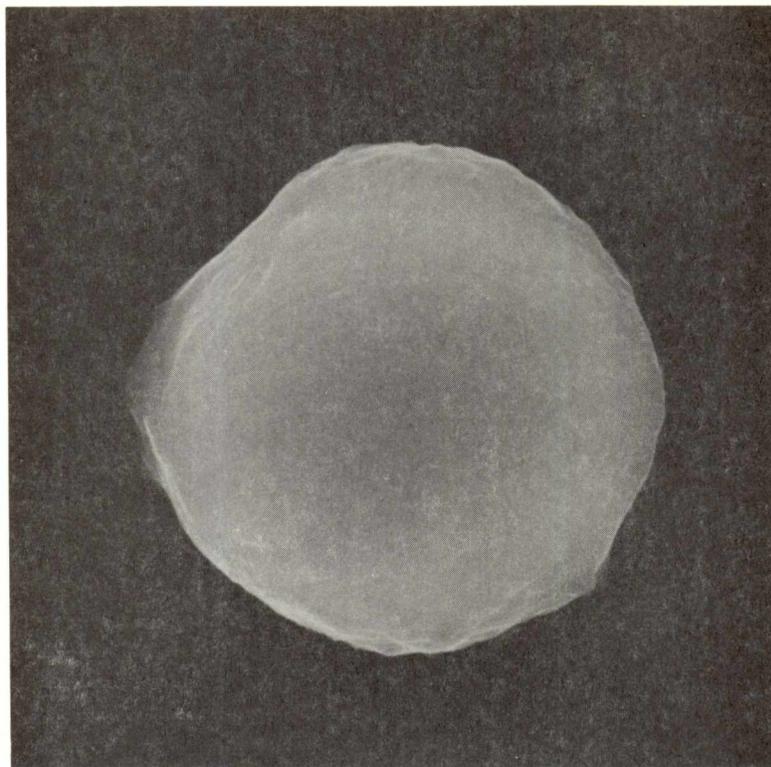
<u>COLOR</u>	<u>LUSTER</u>
Green, Black and Colorless	SM/D

<u>TYPE</u>	<u>COMMENTS</u>
?	Colorless, transparent protuberances

S-85-36043



U2017A7



<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
12	S	O
<u>COLOR</u>		<u>LUSTER</u>
Black		V
<u>TYPE</u>	<u>COMMENTS</u>	
?	May be hollow	

S-85-36044

