



National Aeronautics and
Space Administration

Planetary Materials Branch

Lyndon B. Johnson Space Center
Houston, Texas 77058

Publication 63

JSC 18622

COSMIC DUST CATALOG

(PARTICLES FROM COLLECTION FLAG U2001)

COMPILED BY

COSMIC DUST PRELIMINARY EXAMINATION TEAM (CDPET)

SEPTEMBER 1982

Volume 3
Number 1

COSMIC DUST CATALOG

Volume 3/Number 1

(Particles from Collection Flag U2001)

Compiled by

Cosmic Dust Preliminary Examination Team (CDPET)*

NASA Johnson Space Center
Houston, Texas 77058 U.S.A.

September 1982

*In alphabetical order:

U. S. Clanton¹

E. M. Gabel²

J. L. Gooding¹

A. M. Isaacs³

I. D. R. Mackinnon⁴

D. S. McKay¹

G. A. Nace³

J. L. Warren²

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

⁴Mackinnon Consulting Service, 15911 Parksley, Houston, Texas 77059

CONTENTS

	<u>Page No.</u>
1. INTRODUCTION	iii
2. PROCESSING OF PARTICLES	v
3. PRELIMINARY EXAMINATION OF PARTICLES	vi
4. CATALOG FORMAT	vii
5. ANALYSES OF REFERENCE MATERIALS	xiii
6. SAMPLE REQUESTS	xxii
7. ACKNOWLEDGEMENTS	xxiii
PARTICLE DESCRIPTIONS	1

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 (altitude ~ 18 km). Specially designed dust collectors experience pre- and post-flight handling in an ultraclean 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 material for scientific study.

This catalog summarizes preliminary observations on some of the particles retrieved from collection surface U2001. U2001 was one of two flat plate "flags" (each with 30 cm^2 surface area) which were coated with silicone oil and then flown aboard a NASA U-2 aircraft during a series of flights across the United States from March 13 to April 8, 1982. The flags were installed in specially constructed wing pylons which ensured that the necessary level of cleanliness was maintained between periods of active sampling. Flights on March 13, 22, 23, and 25 were made over Kansas and western Nebraska. On March 30, the aircraft flew from Kansas to Wallops Island, Virginia and, on April 1 and 4, from Wallops Island to an area west of Florida and over the Gulf of Mexico. On April 8, the aircraft flew from Wallops Island to its home base at Moffett Field, California. During those successive periods of high-altitude ($\sim 65,000$ ft.) cruise, the flags were exposed to the atmosphere by pilot command and then retracted into sealed storage containers prior to descent. In this manner, a total of 31 hours of stratospheric exposure was accumulated for Flag U2001.

Flag U2001 is notable for its relatively sparse but significant content

of probable volcanic ash particles. The collection flights of April 4 and 8 occurred both temporally and geographically close to the April 4 explosive eruption of the El Chichón, Mexico, volcano which injected a large volume of particulate material into the stratosphere. Although U2001 was not heavily contaminated as were Flags W7033 through W7040 flown in May (see Cosmic Dust Courier No. 2, p. 13-14), El Chichón ash appears to be the most likely source of many of the particles cataloged here as "TCN" or "TCN?" (see Section 4 for explanation of particle types). These "TCN" particles appear to be significantly different than those identified as ash on Flags W7033 through W7040 and probably represent early fallout from the El Chichón eruption cloud. The ash particles may represent a valuable resource in the study of the weather and climate effects of volcanic eruptions into the stratosphere.

Despite the occurrence of the ash particles, many extraterrestrial particles having no obvious signs of volcanic contamination were successfully retrieved from Flag U2001.

Details of particle collection, processing, and examination techniques will be published in the future. However, the following information summarizes these techniques so that the catalog can be more fully understood and utilized.

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 $\sim 3 \times 6 \times 24$ 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 micromanipulators under a binocular stereomicroscope. Each particle is positioned on an aluminum-free area of a Freon-cleaned, carbon-coated mount 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.

Next, each mount (with uncoated particles) is examined by SEM. A JEOL 100CX STEM, equipped with PGT 6000 solid-state x-ray analyzer, is used to obtain a secondary-electron image and a raster-scanned energy-dispersive x-ray spectrum (EDS) of each whole particle. The STEM is operated in the SEM mode at an accelerating voltage of 40 kV and the EDS is obtained for the range of 0-10 keV by a standard integrated count of 100 sec. SEM images so obtained are necessarily of relatively low resolution due to the deliberate avoidance of conventionally applied conductive coats (carbon or gold-palladium) which might interfere with later elemental analyses of particles.

An important property of the EDS spectra in this catalog is the absence of significant STEM system peaks. Cosmic Dust Catalog Volumes 1 and 2, and Cosmic Dust Courier issues No. 1 and 2, all contained EDS spectra with extraneous copper x-ray peaks from STEM internal parts. However, that problem has now been corrected so that copper peak artifacts are negligible (Cu-K α peak count rate $\leq 1.5/\text{sec}$). Therefore, EDS spectra with "CU" peaks above background indicate copper-bearing samples.

Following SEM preliminary examination, each 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. Although color perception may vary with observer, the distinction of dark (Dk.) from light (Lt.) particles is unambiguous. Similarly, the distinction of colorless (CL) from colored particles is only occasionally in doubt. 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). Lustres 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 proper 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 which we hope our program 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. 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 "?" or "TCA?". (Based on work by D.E. Brownlee and collaborators, AOS particles are thought to be products of solid-fuel rocket exhausts. They are included here to provide a complete description of the U2001 collection.)

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.)

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 quartz, feldspar, or silicic volcanic glass, three phases 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 some of the reference particles described in "ANALYSES OF REFERENCE MATERIALS".

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.

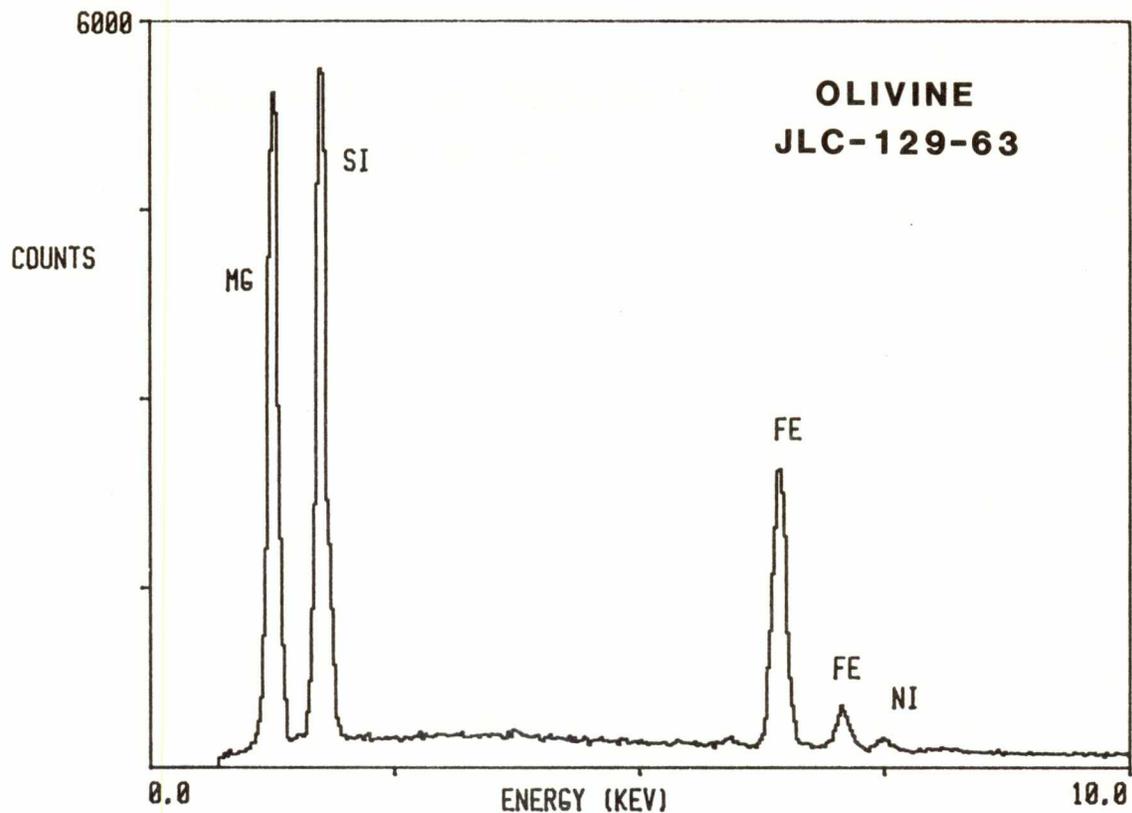
COMMENTS are included for particles with special features or histories. Particles lost during or after preliminary SEM examination, or particles with possible genetic relationships to other particles are noted here.

5. ANALYSES OF REFERENCE MATERIALS

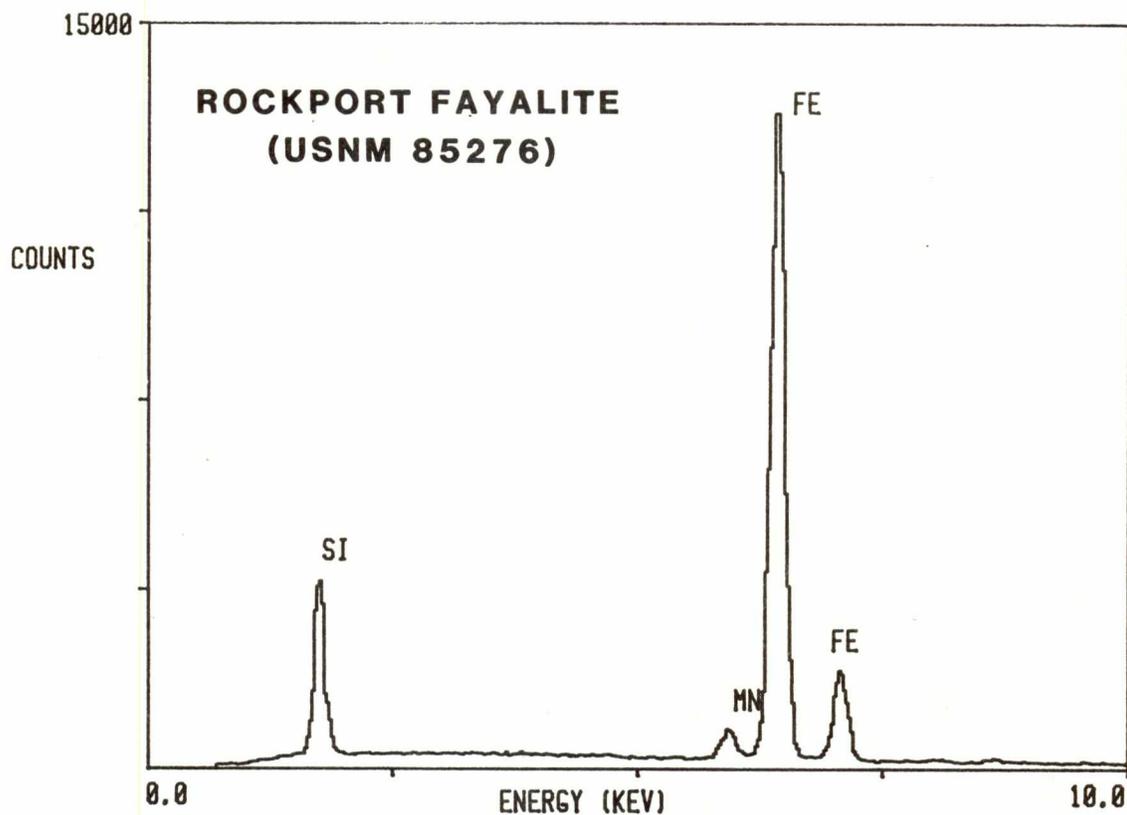
The usefulness of the SEM images and EDS spectra provided for particles in this catalog is enhanced by comparison with similar data products obtained for comparably sized particles of known composition. Accordingly, the next several pages summarize data acquired by EDS analysis of reference particles under the same conditions used in the preliminary examination of particles from the stratospheric dust collections. Each reference particle represents material which has proven useful as a reference (which may be distinct from an analytical standard) in SEM and/or electron microprobe work at JSC or elsewhere. Included in this group are several members of the excellent series of microprobe standards prepared by Eugene Jarosewich (Smithsonian Institution) and identified by their USNM numbers. Other materials will be added to our reference suite in future catalogs. However, those included here provide a sampling of minerals common in meteorites (olivine, pyroxene, ilmenite) or their ablation products (magnetite). A representative EDS spectrum obtained from a pressed pellet of Jarosewich's homogenized Allende chondrite powder is included as an example of a spectrum which should be typical of bulk carbonaceous chondrite material. In addition, reasonable analogs of stratospheric volcanic ash (rhyolite glass, sodic plagioclase) are included. For completeness, the currently accepted bulk composition (expressed as oxide weight percent) of each reference sample is also provided.

The EDS spectra included in this catalog are of quality equal to that which is routinely obtained in other state-of-the-art SEM laboratories. However, well-known geometrical and differential matrix effects prevent these raw spectra from being interpreted as quantitative analyses. Hence, we have avoided the use of peak-height ratios as diagnostic compositional indicators.

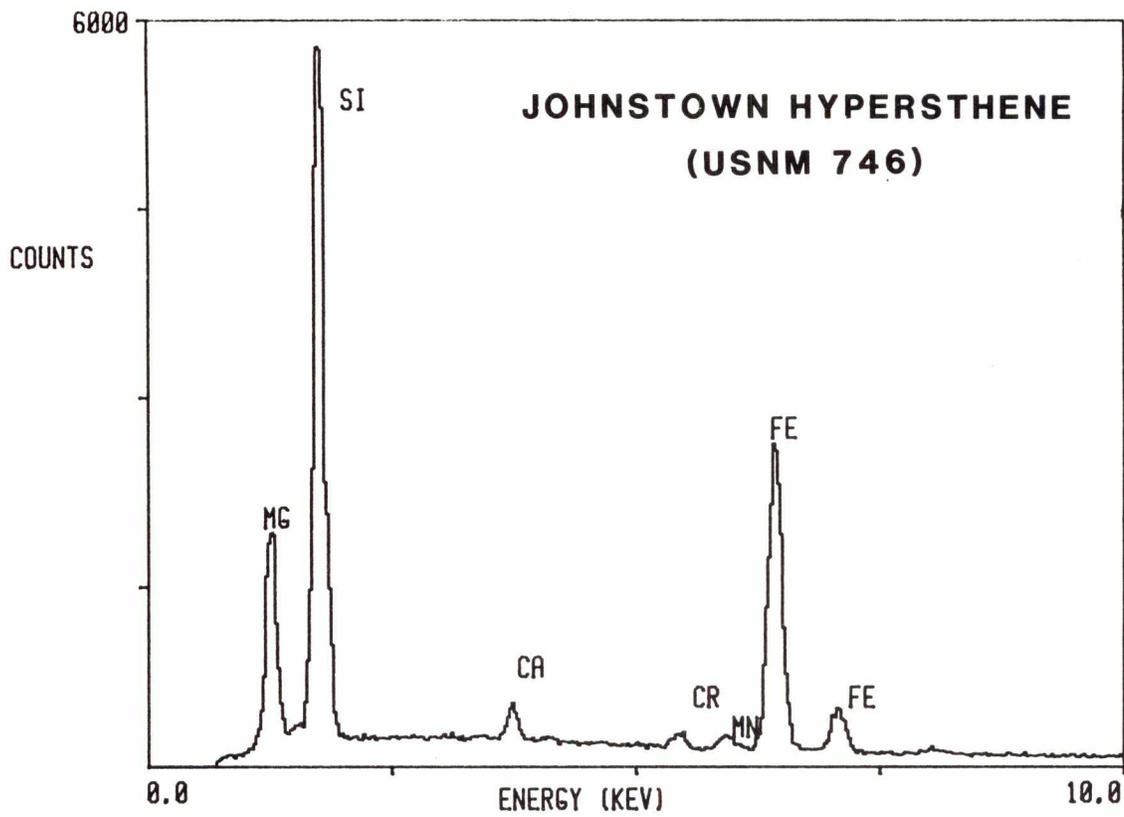
In addition to the EDS spectra of whole reference particles, a typical EDS spectrum is presented for each of three standard minerals prepared as polished grain mounts (San Carlos olivine, USNM 111312/44; diopside JLC-99-63; Kakanui hornblende, USNM 143965). Analyses of these optically flat surfaces eliminate 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.



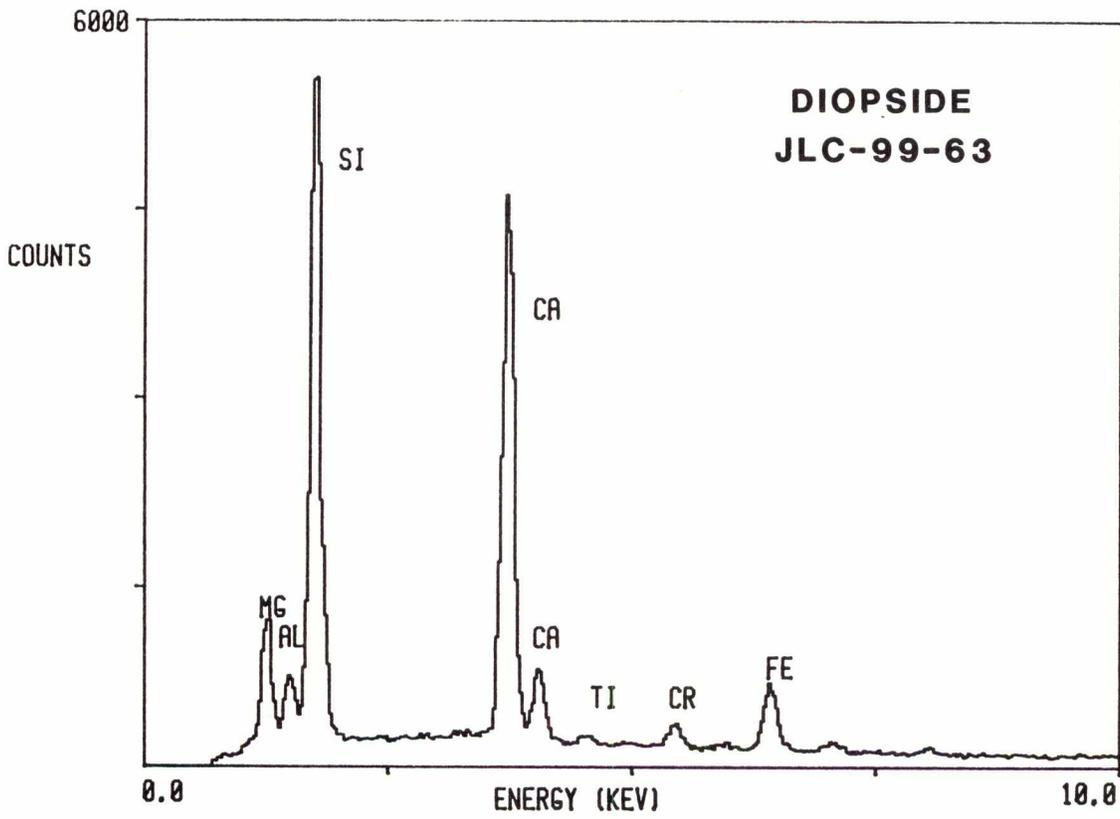
WEIGHT %												
<u>SiO₂</u>	<u>TiO₂</u>	<u>Al₂O₃</u>	<u>Cr₂O₃</u>	<u>Fe₂O₃</u>	<u>FeO</u>	<u>NiO</u>	<u>MnO</u>	<u>MgO</u>	<u>CaO</u>	<u>Na₂O</u>	<u>K₂O</u>	<u>TOTAL</u>
40.94	0.01	0.07	0.01	-	8.74	0.35	0.12	49.64	0.10	-	-	99.98



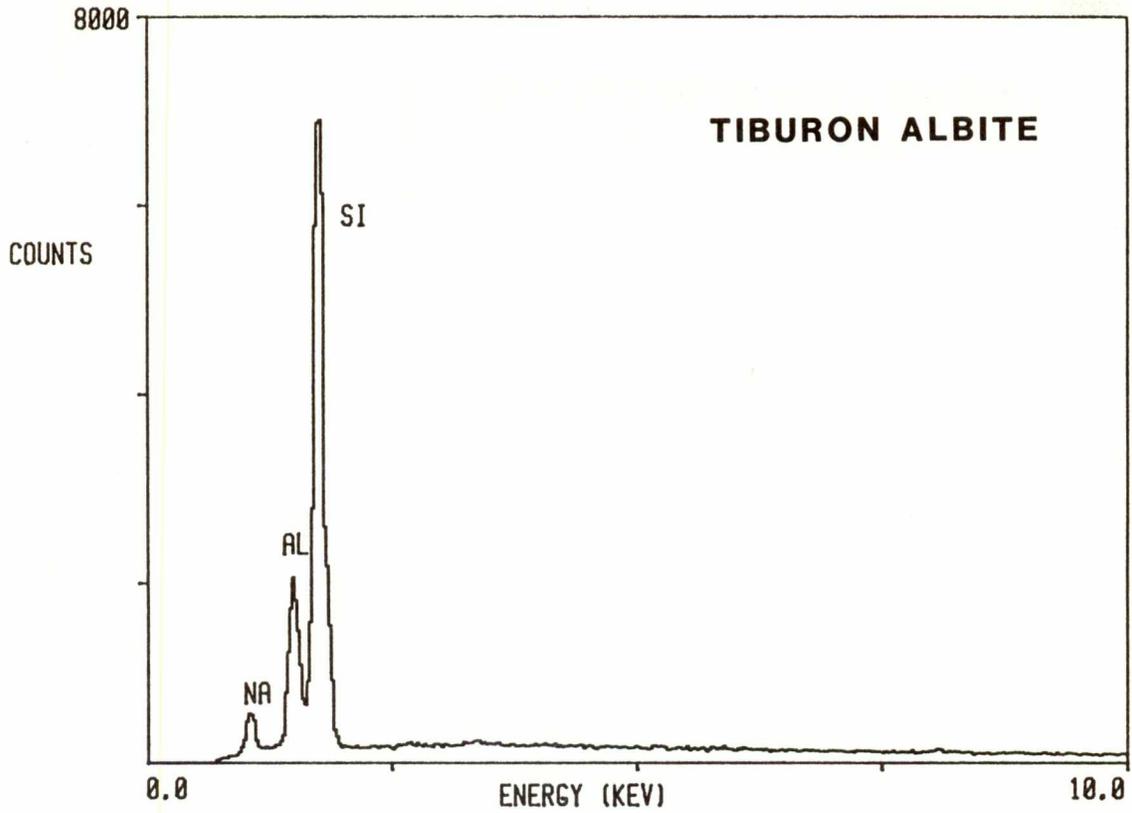
WEIGHT %												
<u>SiO₂</u>	<u>TiO₂</u>	<u>Al₂O₃</u>	<u>Cr₂O₃</u>	<u>Fe₂O₃</u>	<u>FeO</u>	<u>NiO</u>	<u>MnO</u>	<u>MgO</u>	<u>CaO</u>	<u>Na₂O</u>	<u>K₂O</u>	<u>TOTAL</u>
29.22	0.04	-	-	1.32	66.36	-	2.14	-	-	-	-	99.08



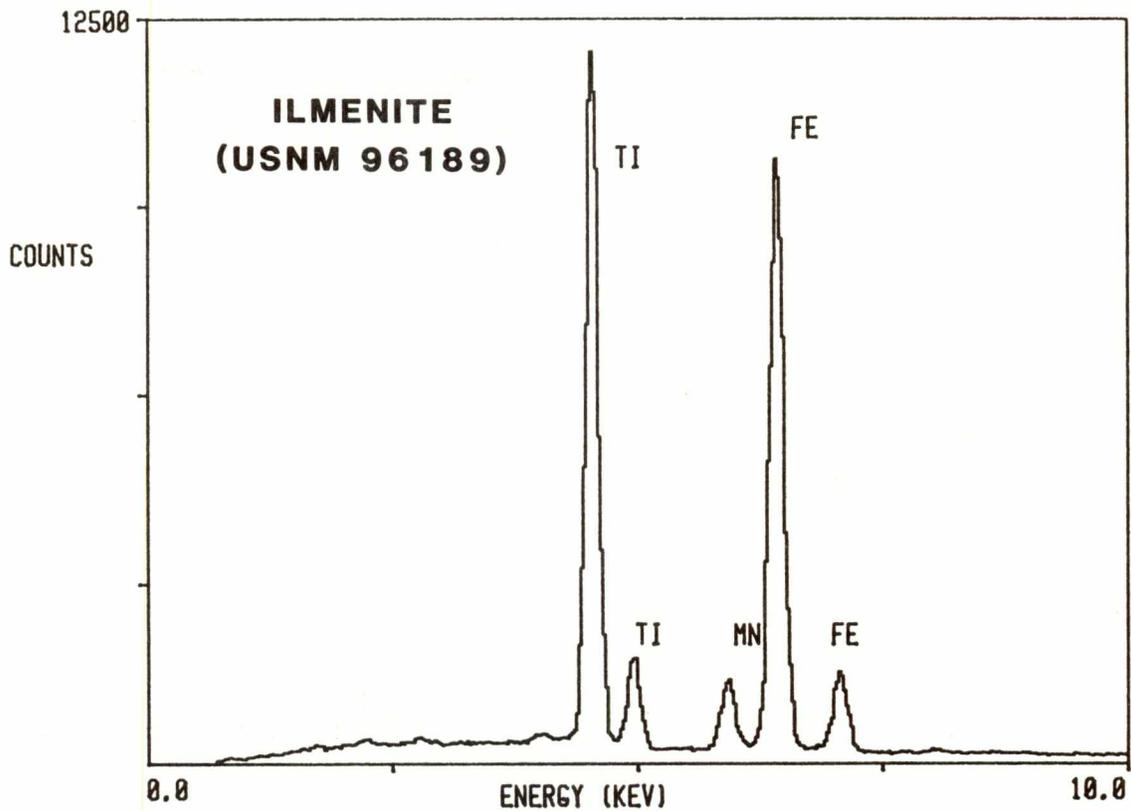
WEIGHT %												TOTAL
SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	NiO	MnO	MgO	CaO	Na ₂ O	K ₂ O	
54.09	0.16	1.23	0.75	-	15.22	-	0.49	26.79	1.52	<0.05	<0.05	100.25



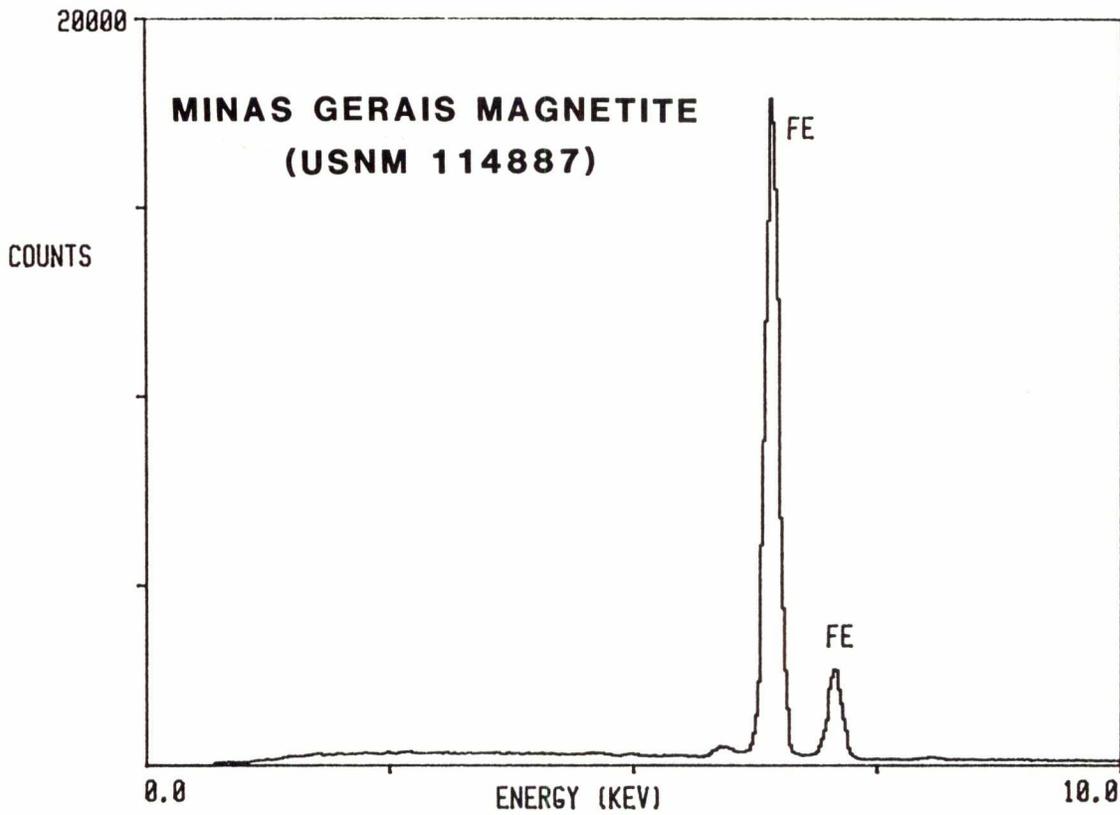
WEIGHT %												TOTAL
SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	NiO	MnO	MgO	CaO	Na ₂ O	K ₂ O	
51.93	0.46	6.31	0.96	1.80	2.34	0.04	0.07	16.05	18.64	1.39	-	99.99



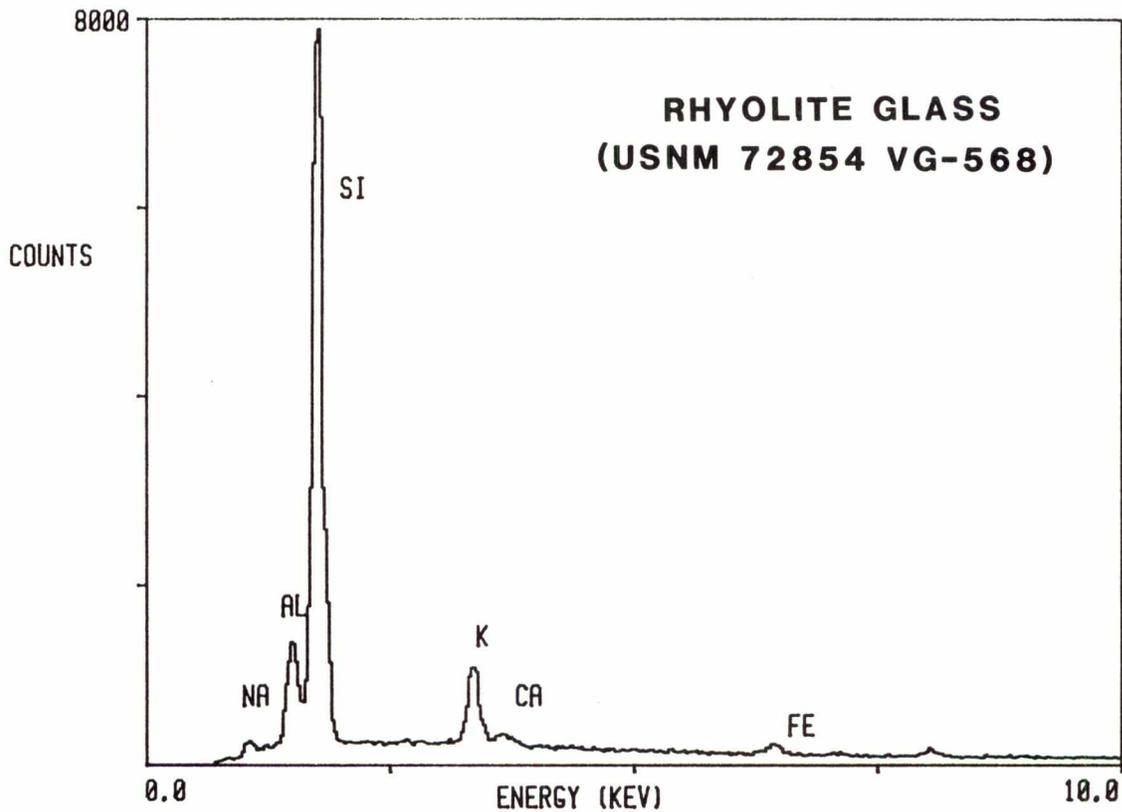
WEIGHT %												TOTAL
<u>SiO₂</u>	<u>TiO₂</u>	<u>Al₂O₃</u>	<u>Cr₂O₃</u>	<u>Fe₂O₃</u>	<u>FeO</u>	<u>NiO</u>	<u>MnO</u>	<u>MgO</u>	<u>CaO</u>	<u>Na₂O</u>	<u>K₂O</u>	
68.22	-	19.90	-	0.06	-	-	-	-	0.00	11.65	0.03	99.86



WEIGHT %												TOTAL
<u>SiO₂</u>	<u>TiO₂</u>	<u>Al₂O₃</u>	<u>Cr₂O₃</u>	<u>Fe₂O₃</u>	<u>FeO</u>	<u>NiO</u>	<u>MnO</u>	<u>MgO</u>	<u>CaO</u>	<u>Na₂O</u>	<u>Nb₂O₅</u>	
-	45.7	-	-	11.6	36.1	-	4.77	0.31	-	-	0.92	99.40

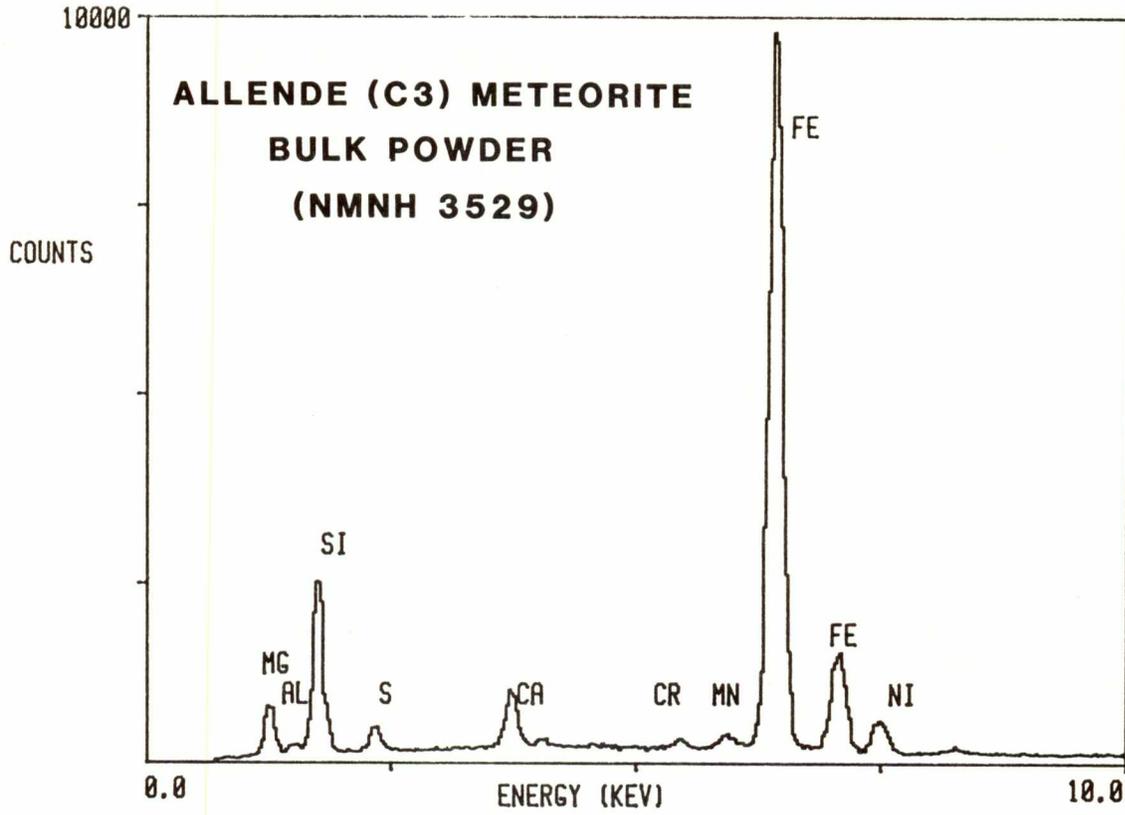


WEIGHT %												TOTAL
SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	NiO	MnO	MgO	CaO	Na ₂ O	K ₂ O	
-	0.16	-	0.25	67.5	30.2	-	<0.01	0.05	-	-	-	98.16

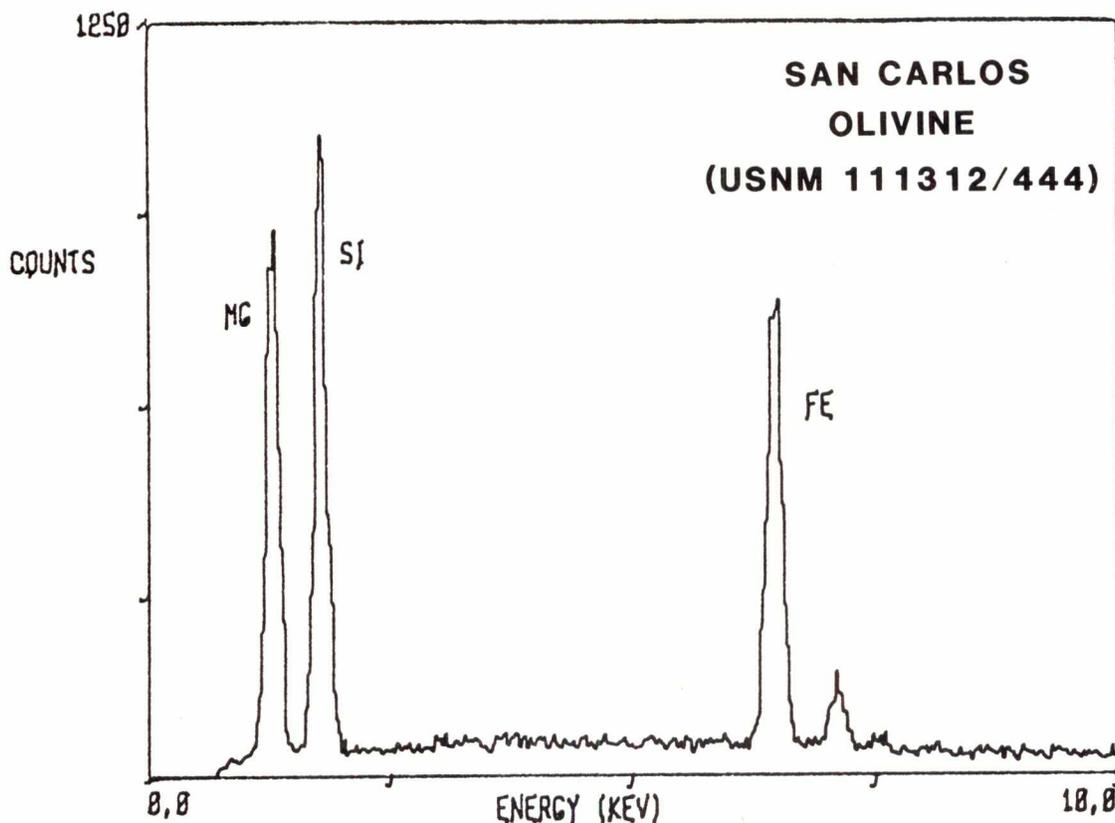


WEIGHT %												TOTAL
SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	Cl	H ₂ O	
76.71	0.12	12.06	0.48	0.80	0.03	<0.1	0.50	3.75	4.89	0.13	0.12	99.56

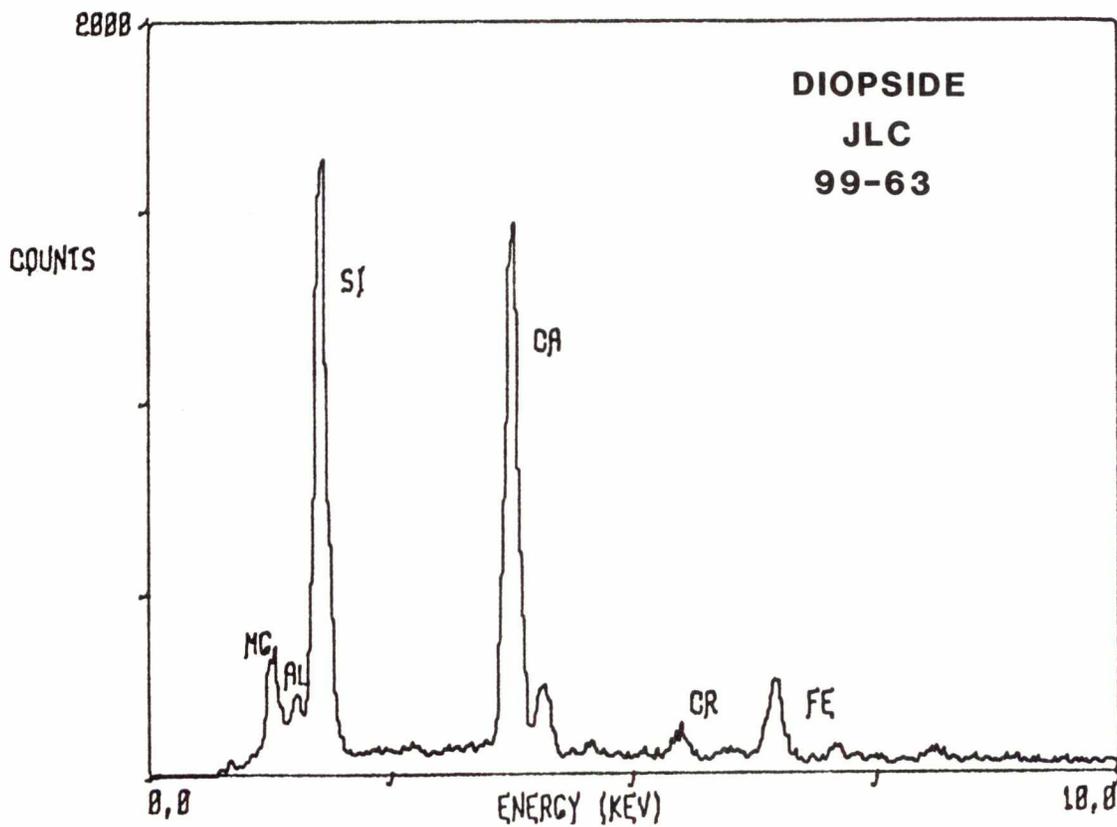
ALL02



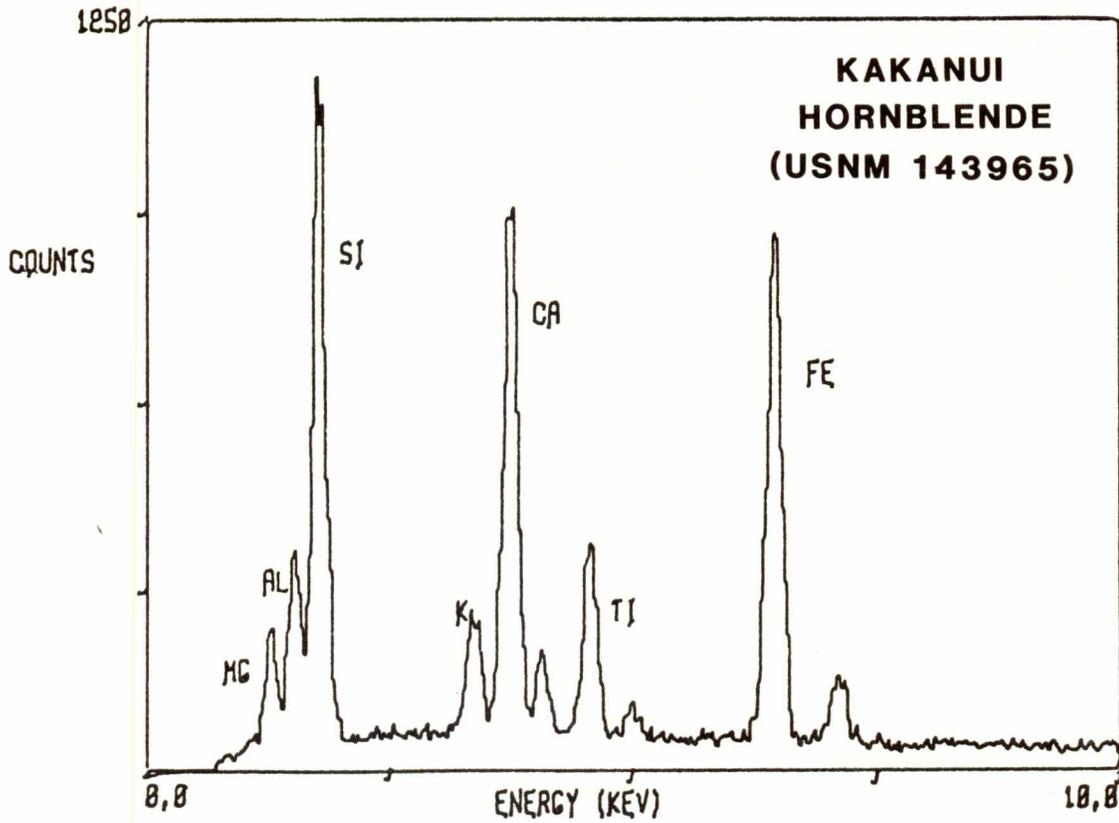
WEIGHT %											
<u>SiO₂</u>	<u>TiO₂</u>	<u>Al₂O₃</u>	<u>Cr₂O₃</u>	<u>FeO</u>	<u>MnO</u>	<u>MgO</u>	<u>CaO</u>	<u>Na₂O</u>	<u>K₂O</u>	<u>P₂O₅</u>	<u>C</u>
34.23	0.15	3.27	0.52	27.15	0.18	24.62	2.61	0.45	0.03	0.23	0.29
<u>FeS</u>	<u>NiS</u>	<u>CoS</u>	<u>Fe^o</u>	<u>Ni^o</u>	<u>Co^o</u>	<u>TOTAL</u>					
4.03	1.60	0.08	0.17	0.36	0.01	99.98					



WEIGHT %													TOTAL
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	
40.81	-	-	-	-	9.55	0.37	0.14	49.42	<0.05	-	-	-	100.29



WEIGHT %													TOTAL
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	
51.93	0.46	6.31	0.96	1.80	2.34	0.04	0.07	16.05	18.64	1.39	-	-	99.99



WEIGHT %													
<u>SiO₂</u>	<u>TiO₂</u>	<u>Al₂O₃</u>	<u>Cr₂O₃</u>	<u>Fe₂O₃</u>	<u>FeO</u>	<u>NiO</u>	<u>MnO</u>	<u>MgO</u>	<u>CaO</u>	<u>Na₂O</u>	<u>K₂O</u>	<u>H₂O</u>	<u>TOTAL</u>
40.37	4.72	14.90	-	3.30	7.95	-	0.09	12.80	10.30	2.60	2.05	0.94	100.02

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) 483-3274
Code SN2
NASA/Johnson Space Center
Houston, Texas 77058
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:

Discipline Scientist, Planetary Materials
Code EL-4
NASA Headquarters
Washington, D.C. 20546

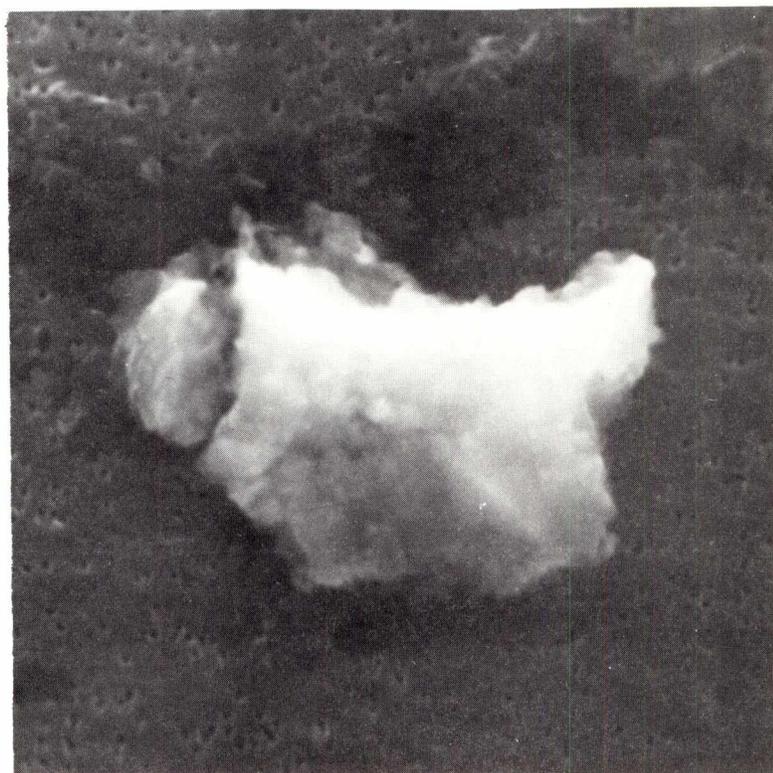
Although foreign scientists are welcome to request samples, NASA cannot provide funds to be spent outside the U.S.A. by citizens of other countries.

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 several mineral standards and Roy S. Clarke, Jr. (also of Smithsonian Institution) generously supplied the Allende chondrite powder.

MOUNT U2001A

U2001A1



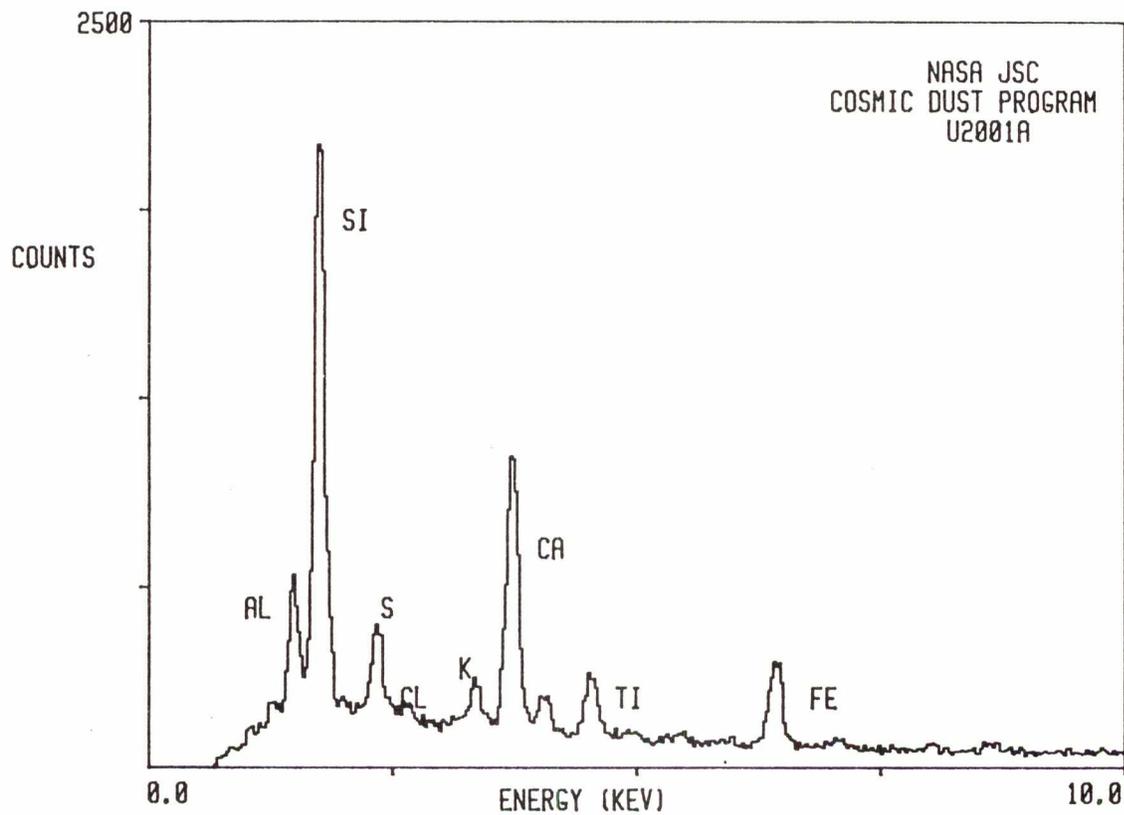
SIZE SHAPE TRANS.
12x16 I 0/TL

COLOR LUSTER
Dk. Gray D/SM

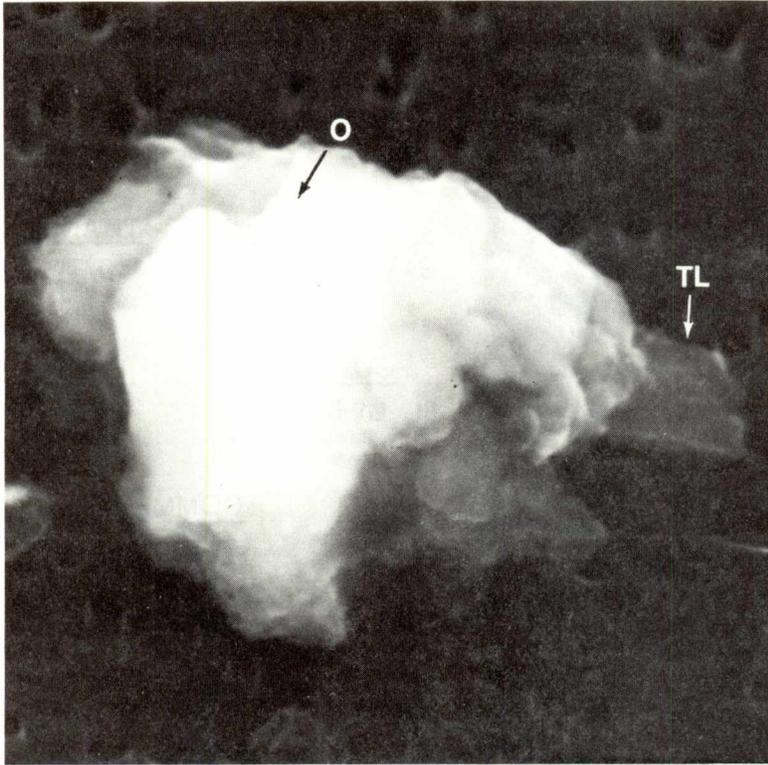
TYPE COMMENTS
TCN? Fragment of ~50
 μm particle
 still on flag

U201A

S-82-34547



U2001A2



SIZE
5x6

SHAPE
I

TRANS.
0/TL

COLOR
Lt. Gray to Black

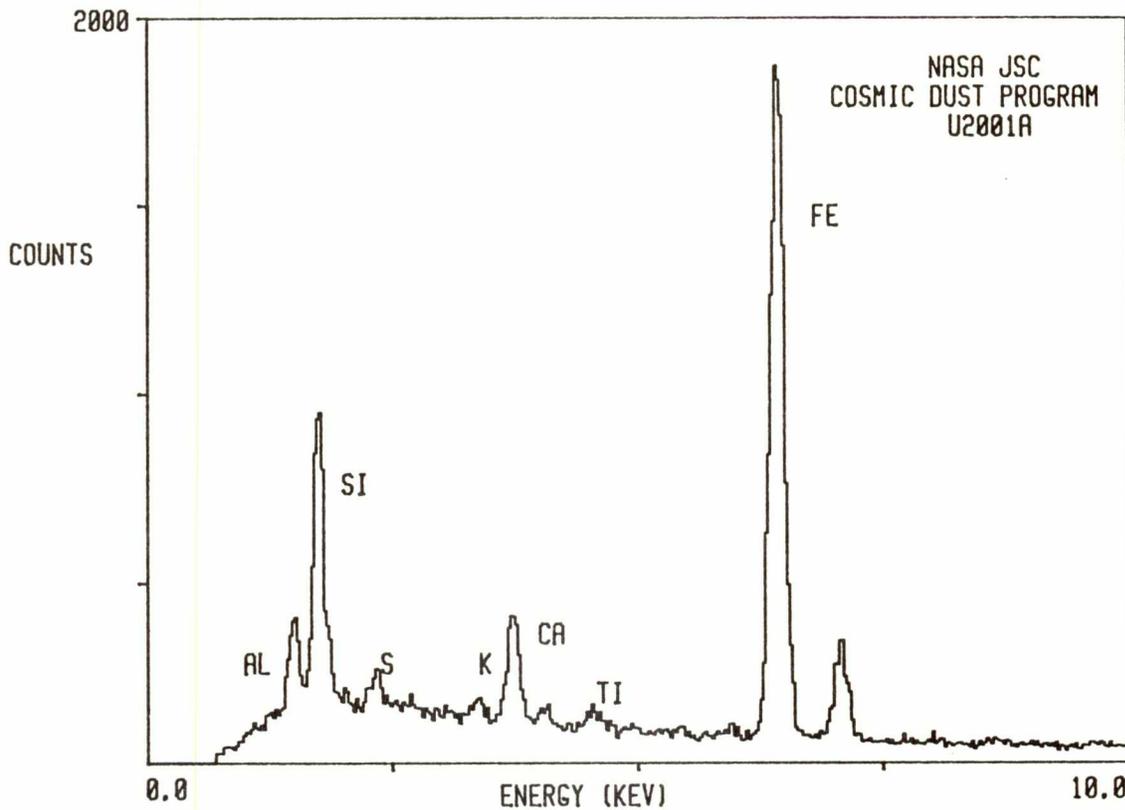
LUSTER
D/SV

TYPE
TCN?

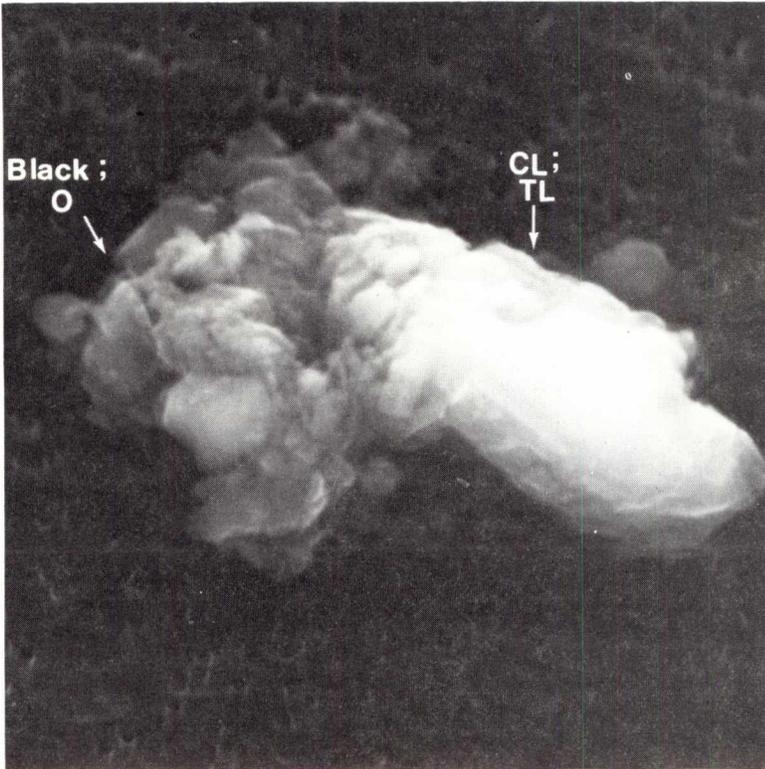
COMMENTS
Derived from
same parent
as for
U2001A1

S-82-34548

U202A



U2001A3



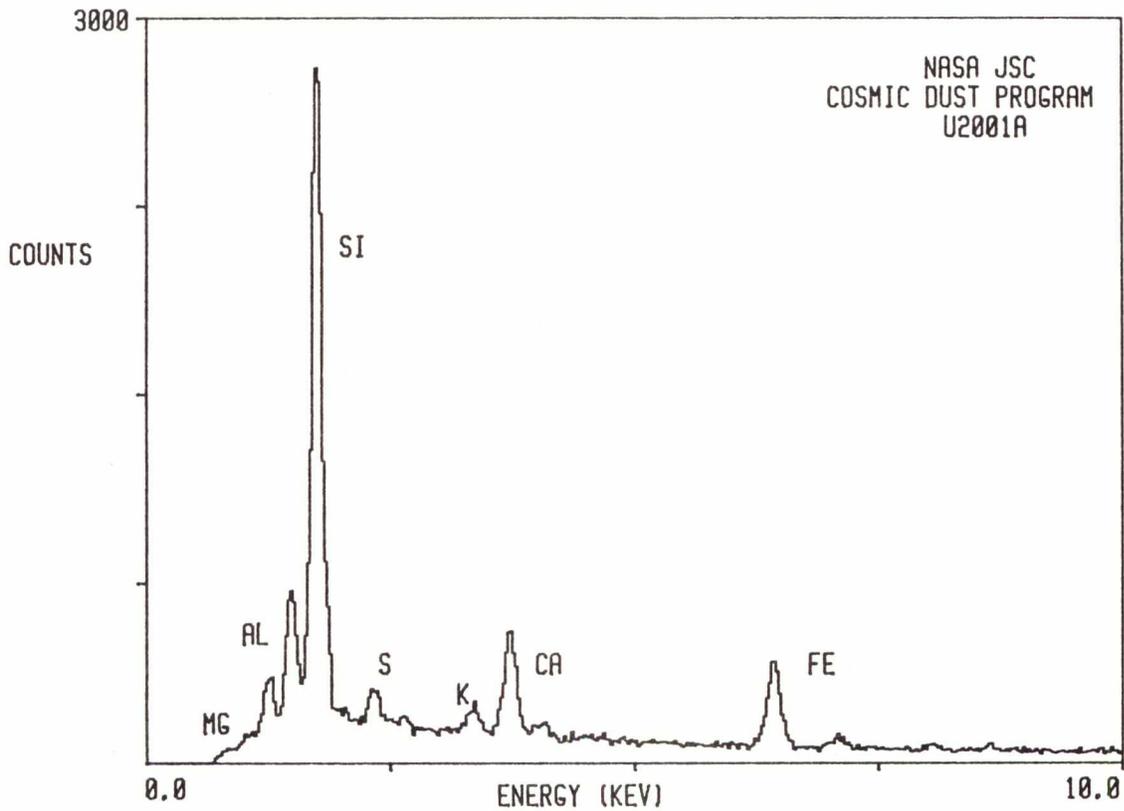
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
9x13	I	O/TL

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

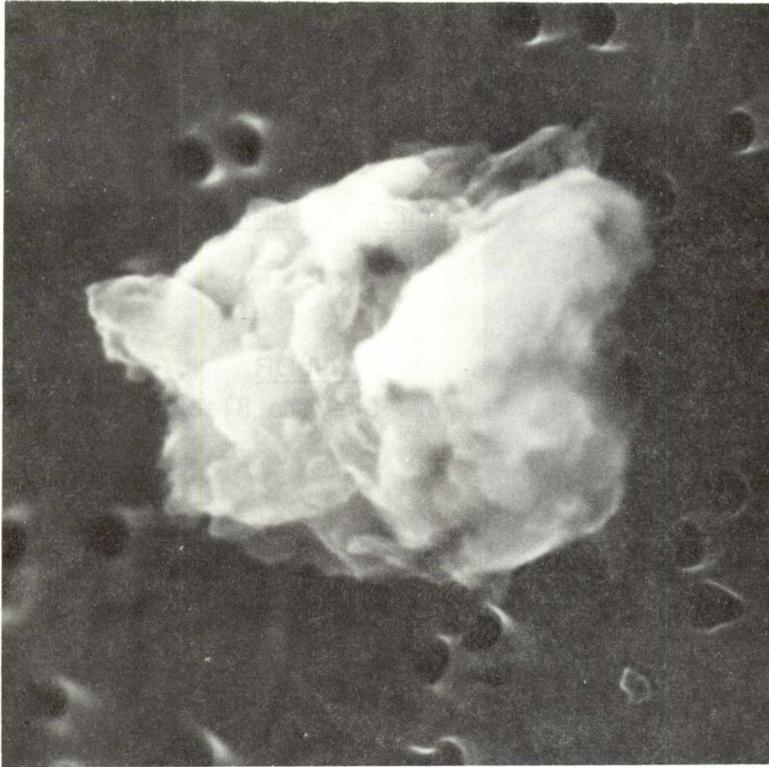
<u>TYPE</u>	<u>COMMENTS</u>
TCN?	Associated with ~40 μ m particle still on flag

U203A

S-82-34549



U2001A4



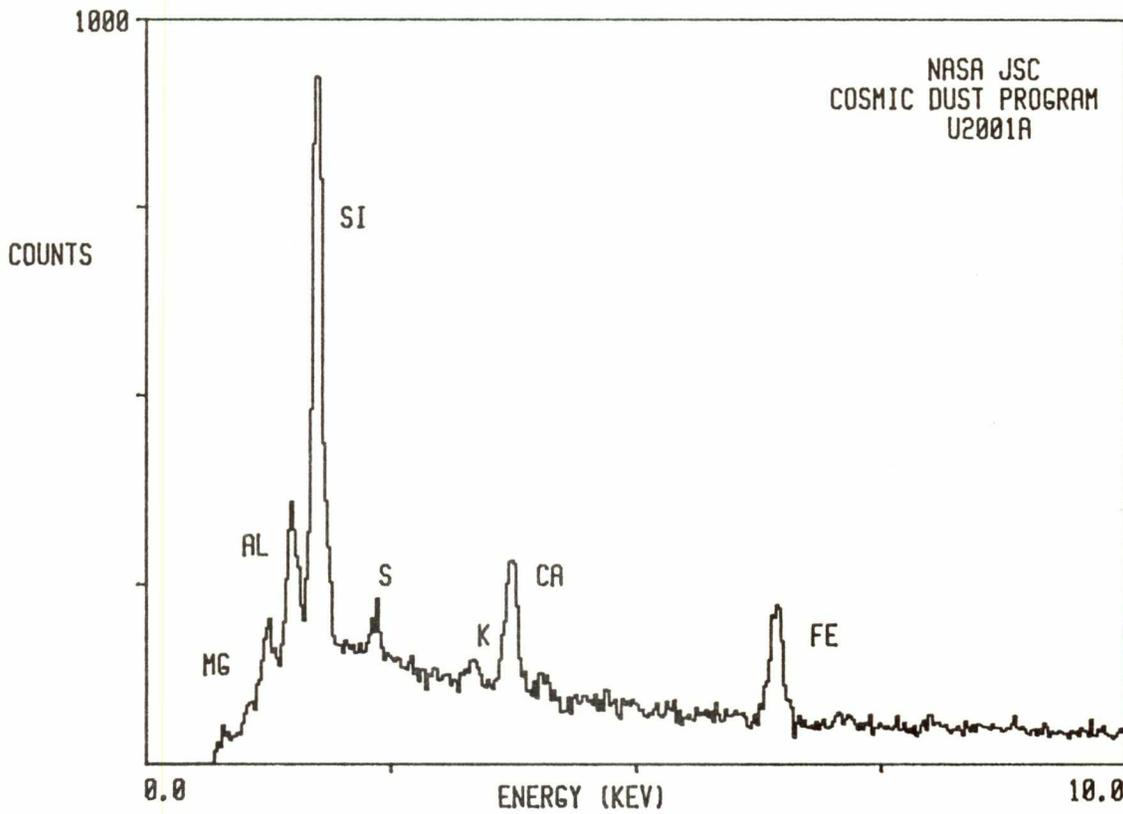
SIZE SHAPE TRANS.
3x4 I 0

COLOR LUSTER
Dk. Gray D/SM

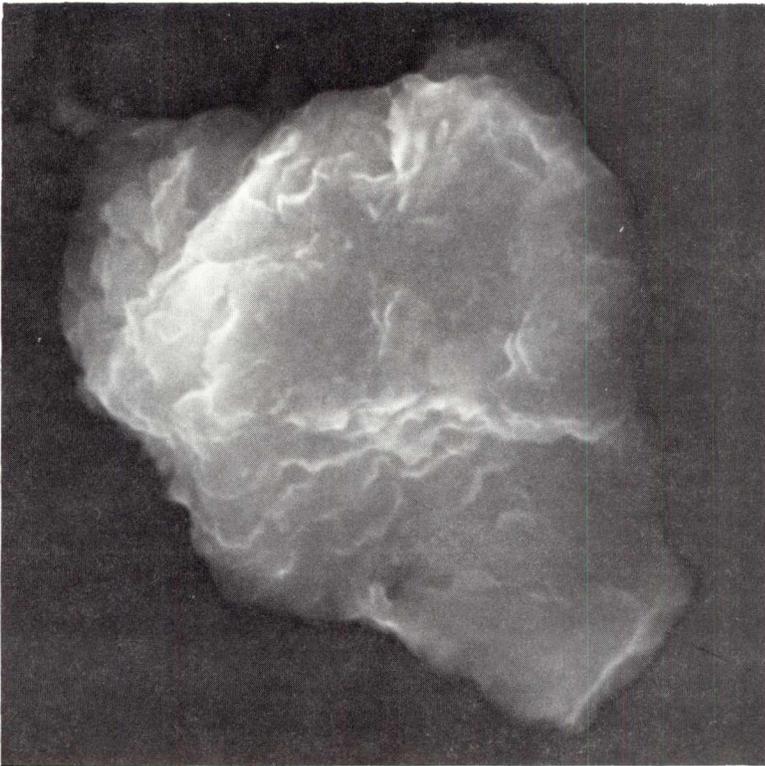
TYPE COMMENTS
TCN? Probably
 related to
 U2001A3

S-82-34550

U201A



U2001A5



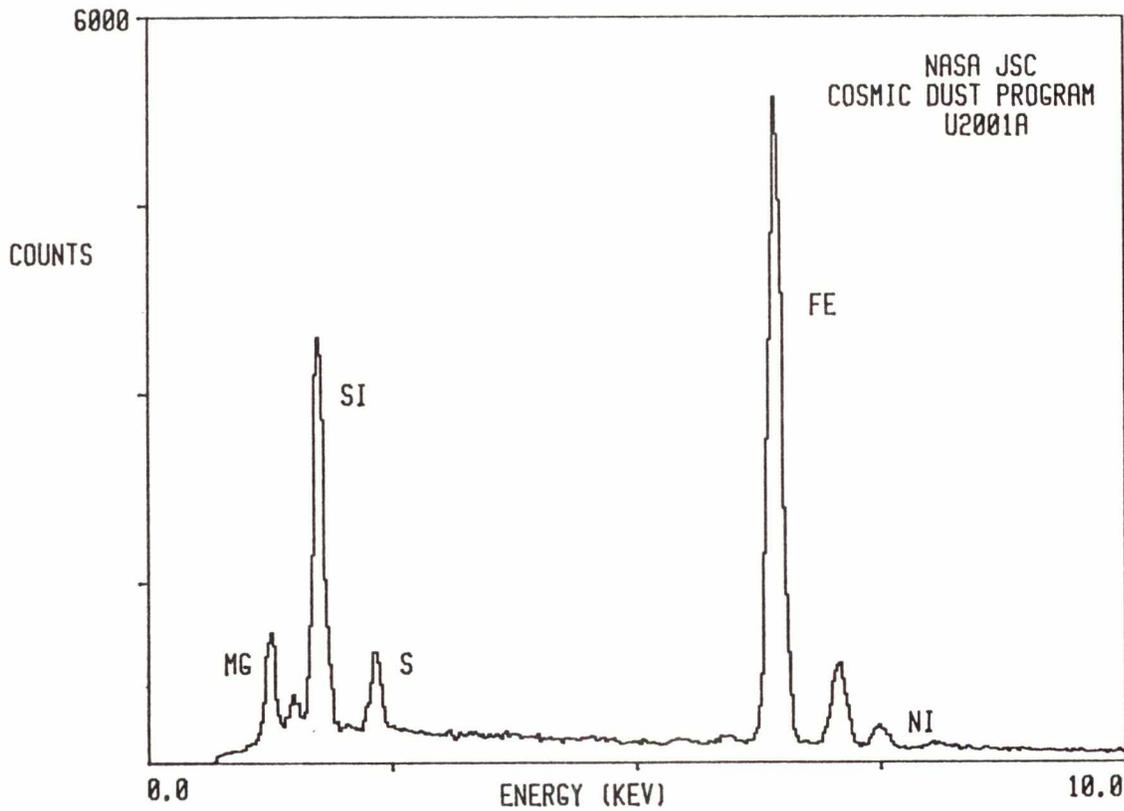
S-82-34551

U205A

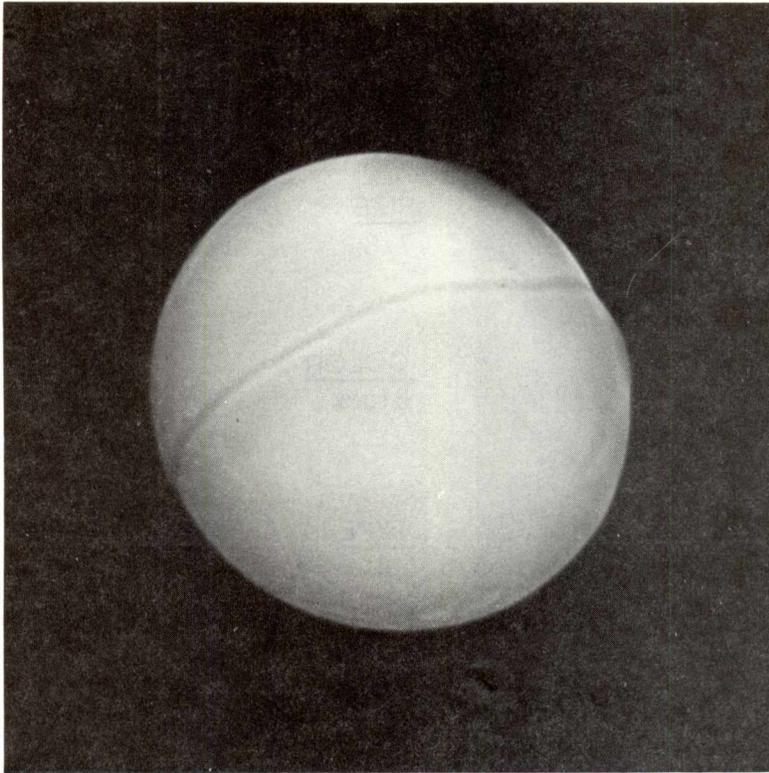
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
21x23	I	0

<u>COLOR</u>	<u>LUSTER</u>
Dk. Gray to Black	D/SM

<u>TYPE</u>	<u>COMMENTS</u>
C	



U2001A6



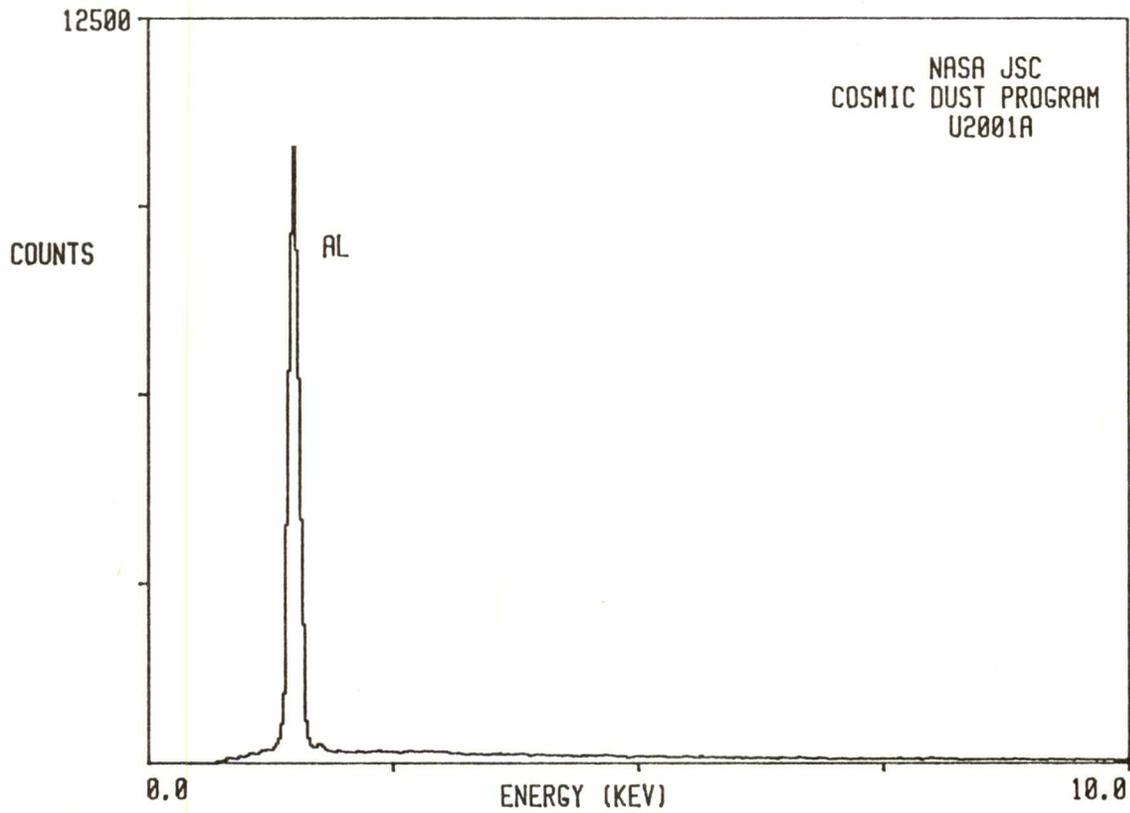
SIZE SHAPE TRANS.
8 S T

COLOR LUSTER
CL to Pale Gray V

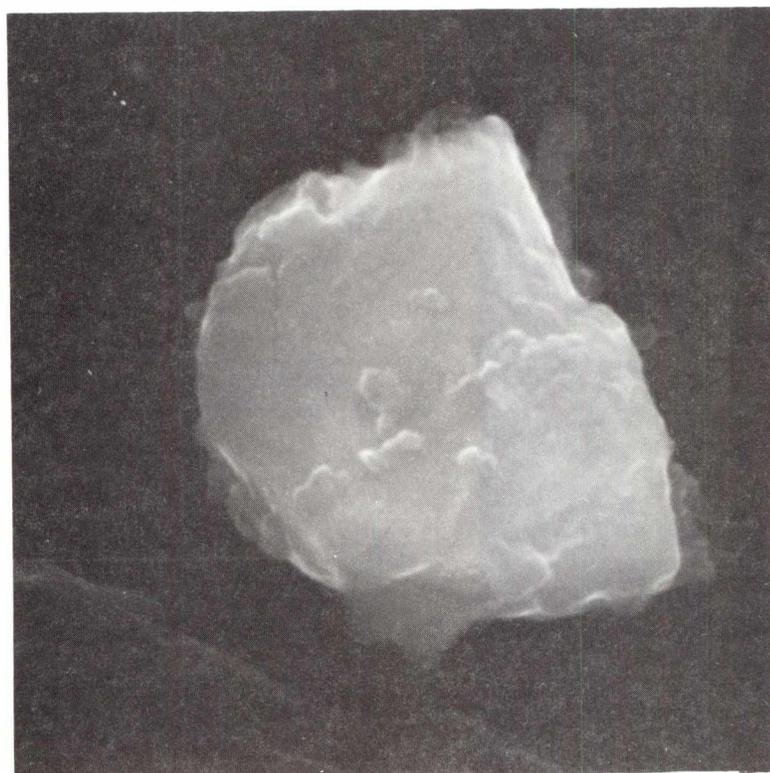
TYPE COMMENTS
AOS

U206A

S-82-34552



U2001A7



SIZE
7x8

SHAPE
I

TRANS.
0

COLOR
Black

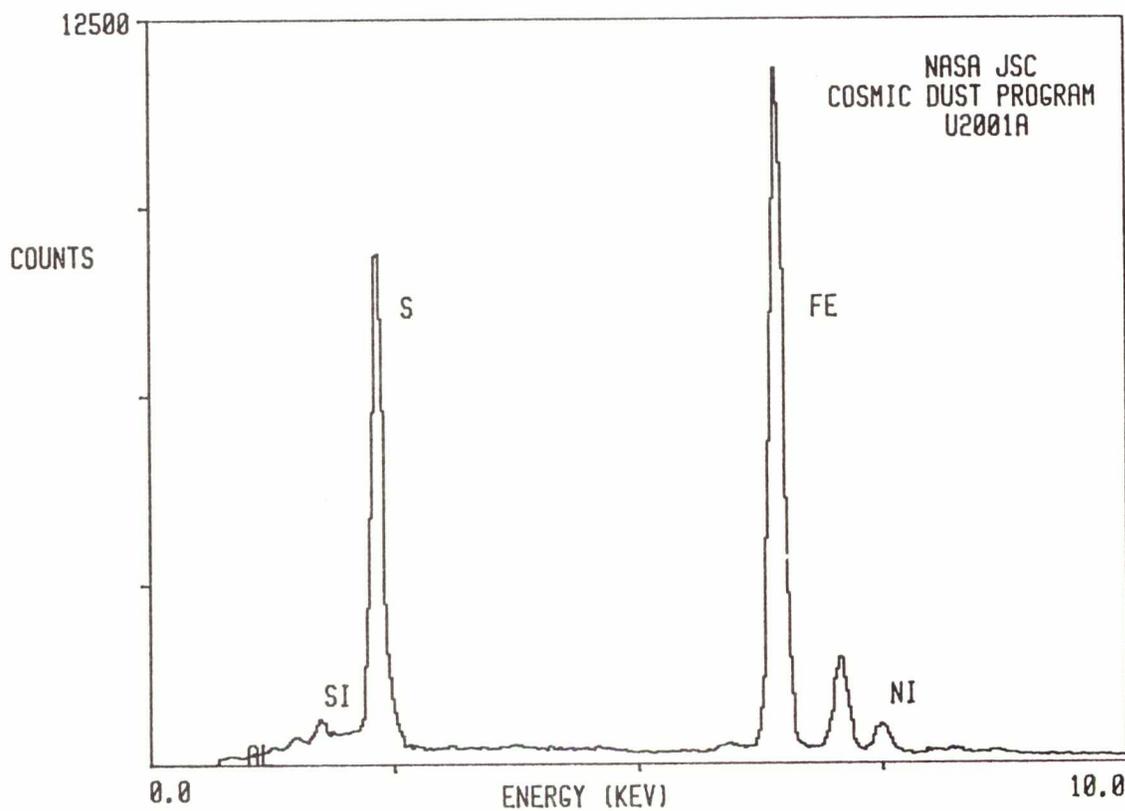
LUSTER
SM

TYPE
C

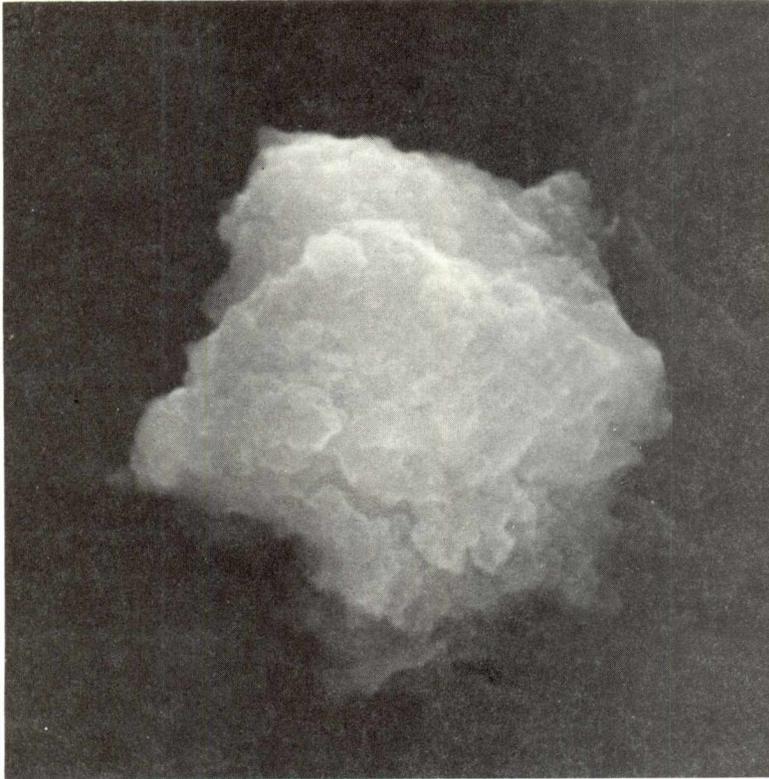
COMMENTS

U207A

S-82-34553



U2001A8



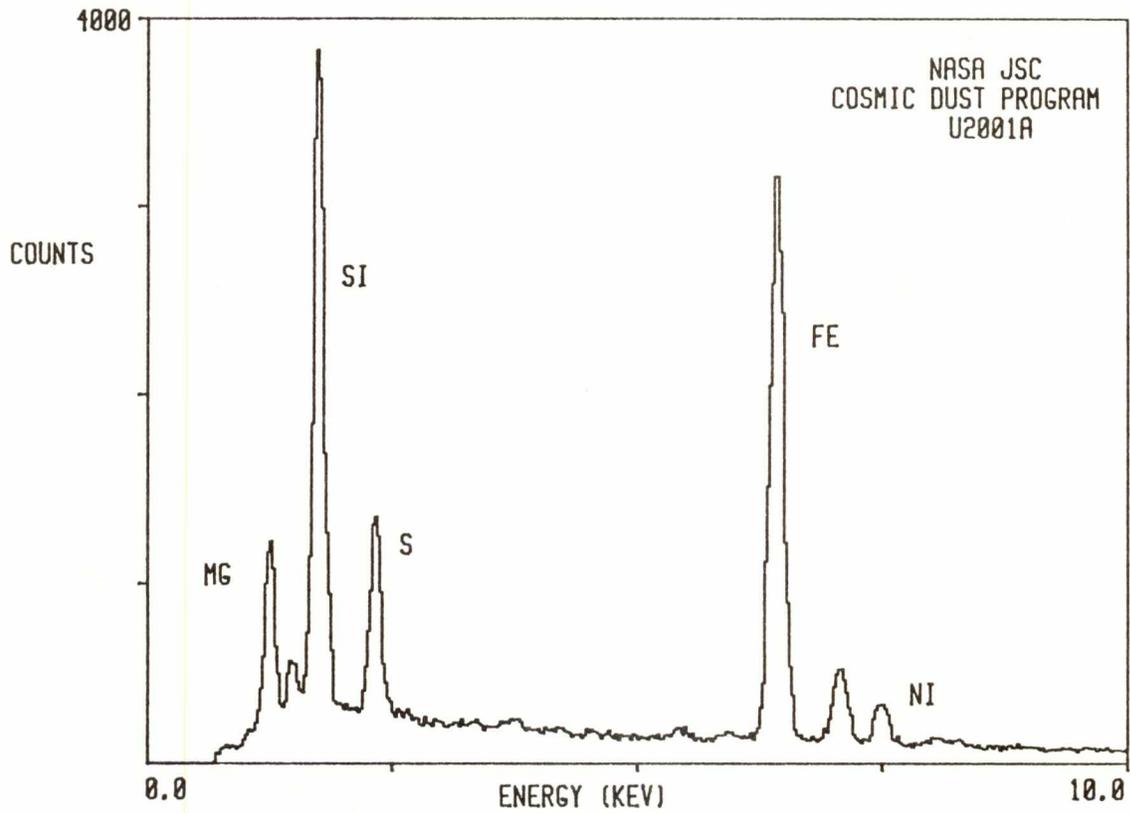
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
16x18	I	0

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

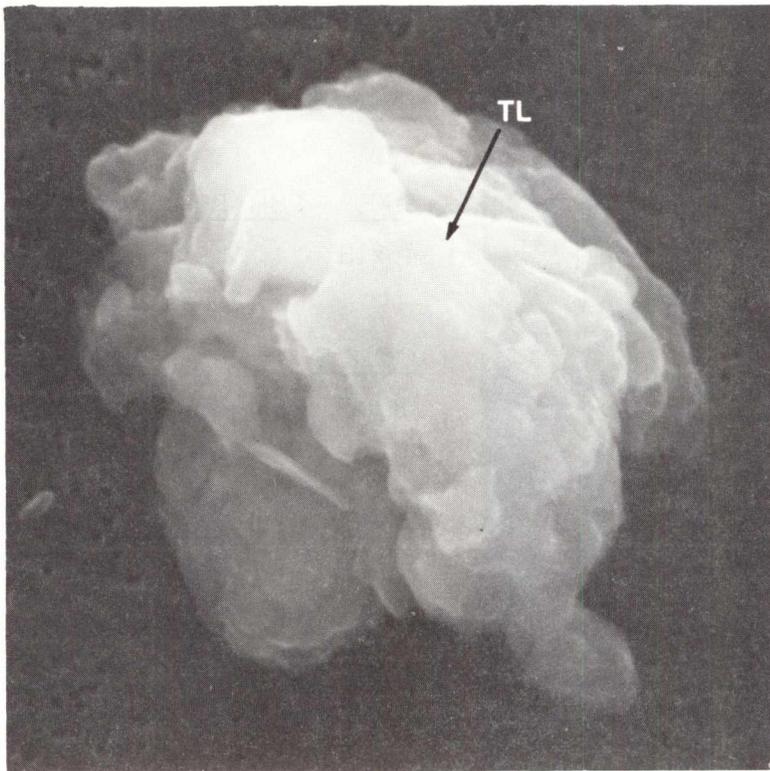
<u>TYPE</u>	<u>COMMENTS</u>
C	

U208A

S-82-34555



U2001A9



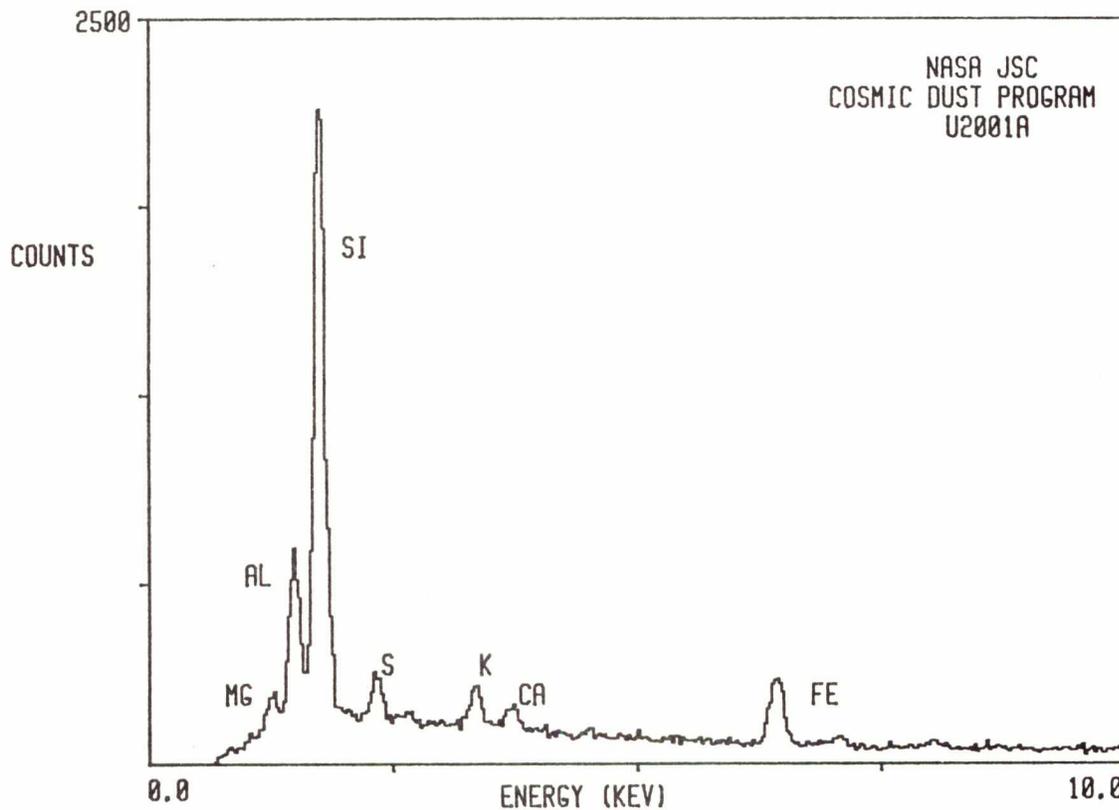
SIZE SHAPE TRANS.
13x18 I 0

COLOR LUSTER
Dk. Gray to Black D/SV

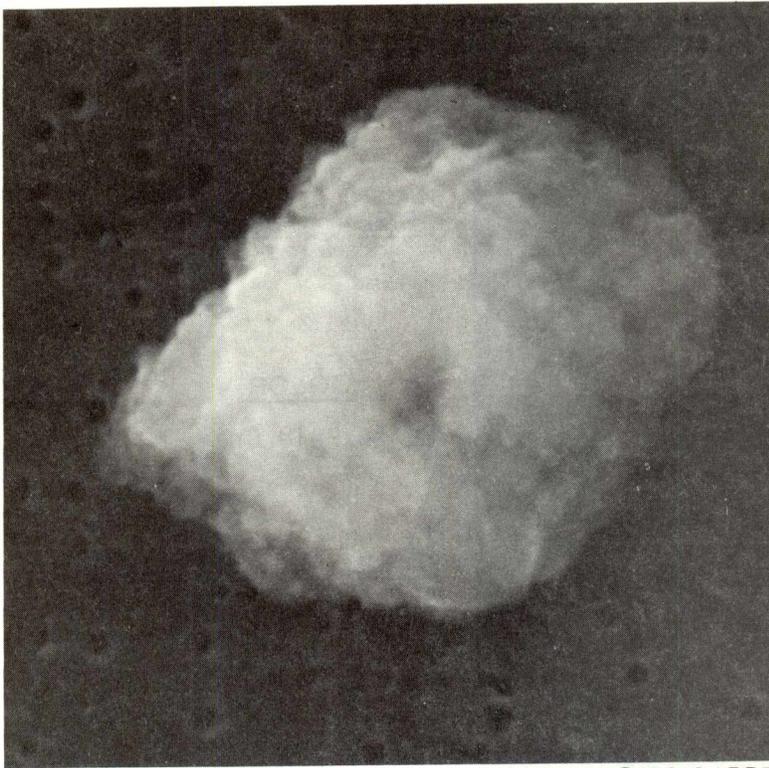
TYPE COMMENTS
TCN

U209A

S-82-34556



U2001A10



SIZE
6x8

SHAPE
I

TRANS.
0

COLOR
Dk. Gray to Black

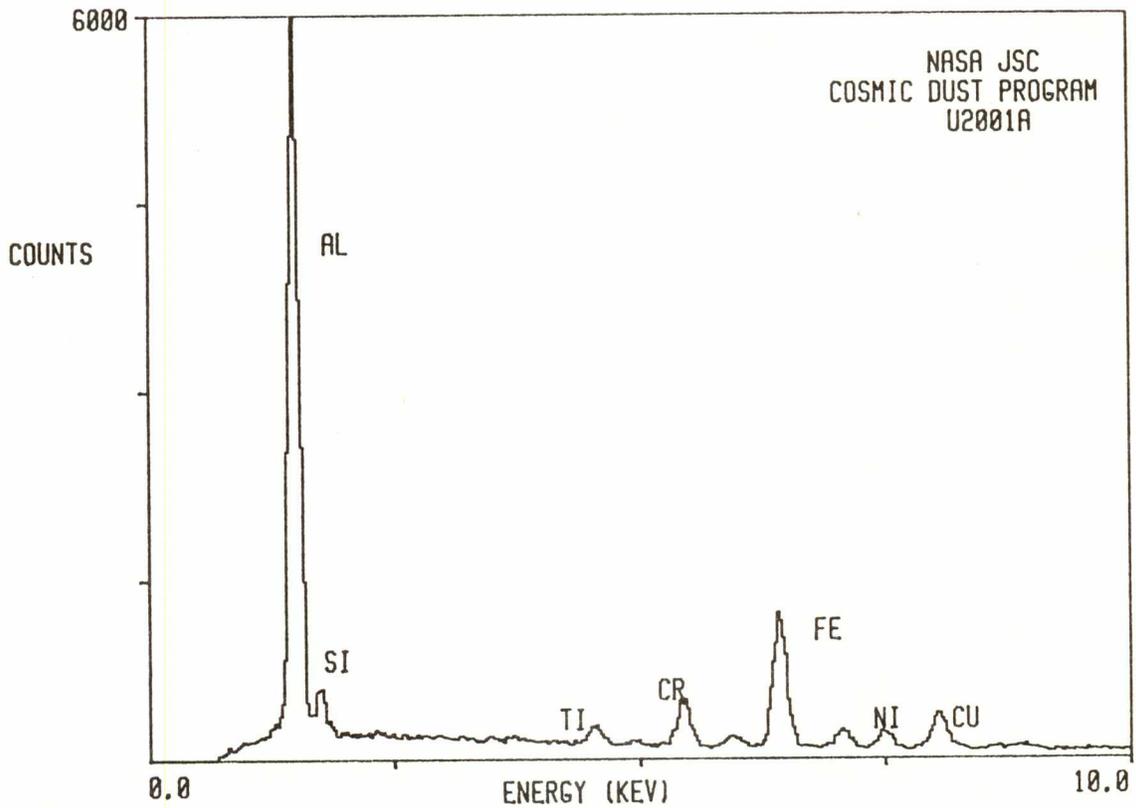
LUSTER
D/SM

TYPE
TCA

COMMENTS

S-82-34557

U210A



U2001A12



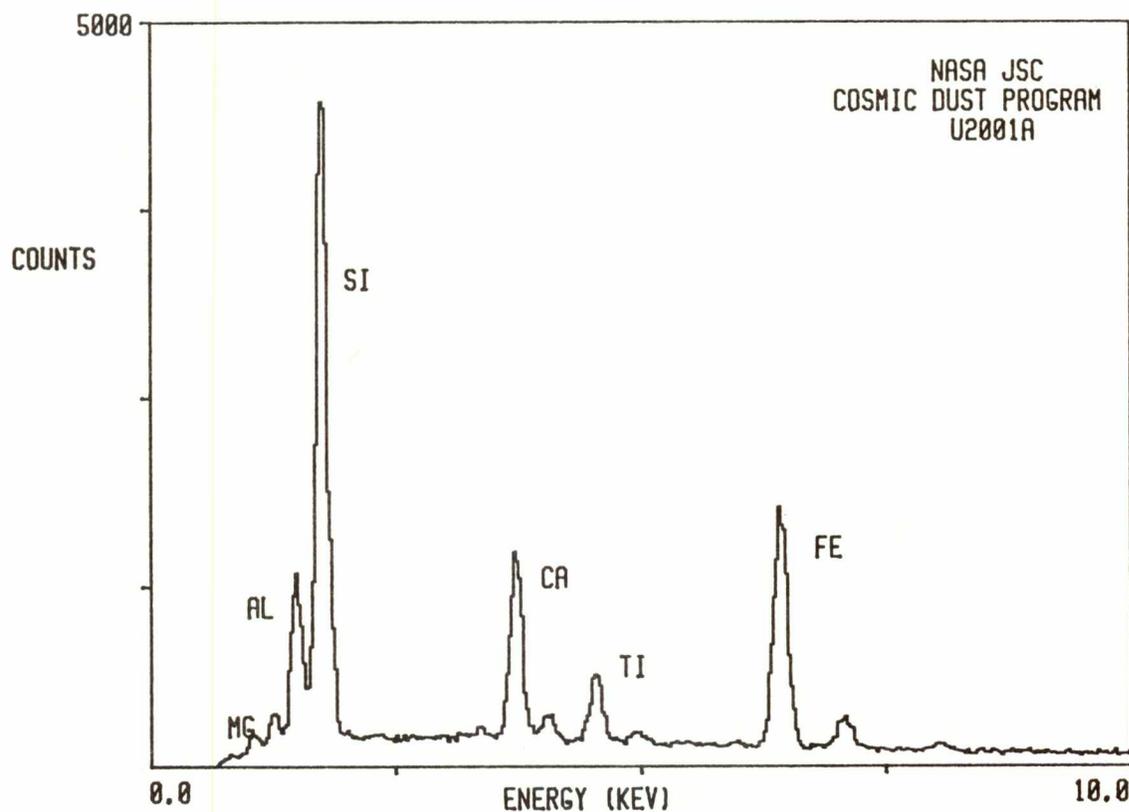
SIZE SHAPE TRANS.
35x39 I TL/0

COLOR LUSTER
Yellow-Orange SV

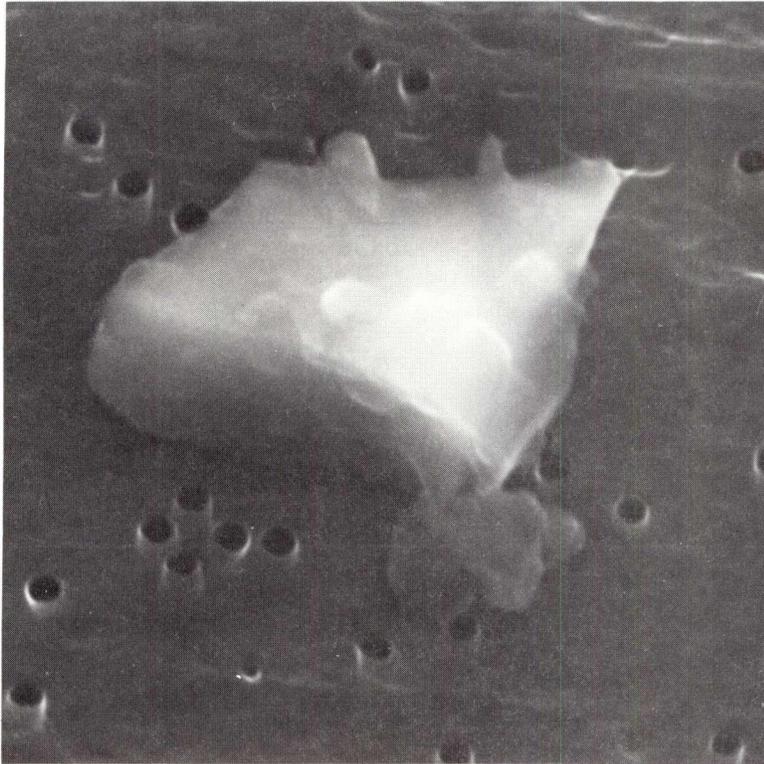
TYPE COMMENTS
TCN

S-82-34559

U212A



U2001A 13



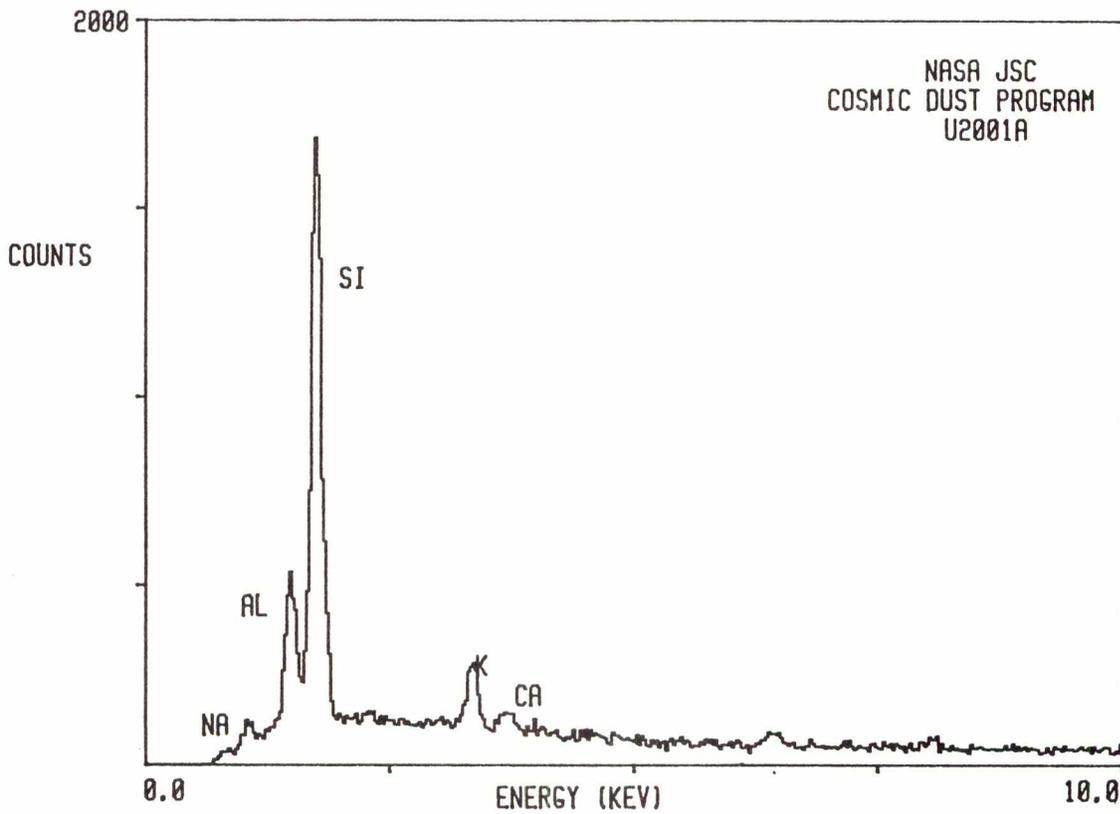
SIZE SHAPE TRANS.
4x5 I T

COLOR LUSTER
CL to Pale Gray V

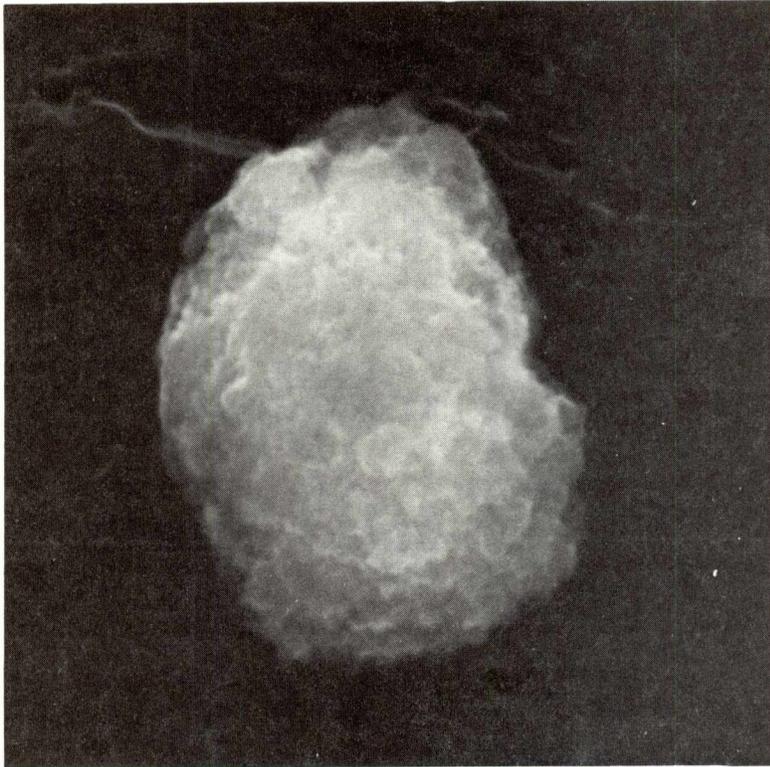
TYPE COMMENTS
TCN

S-82-34560

U213A



U2001A14



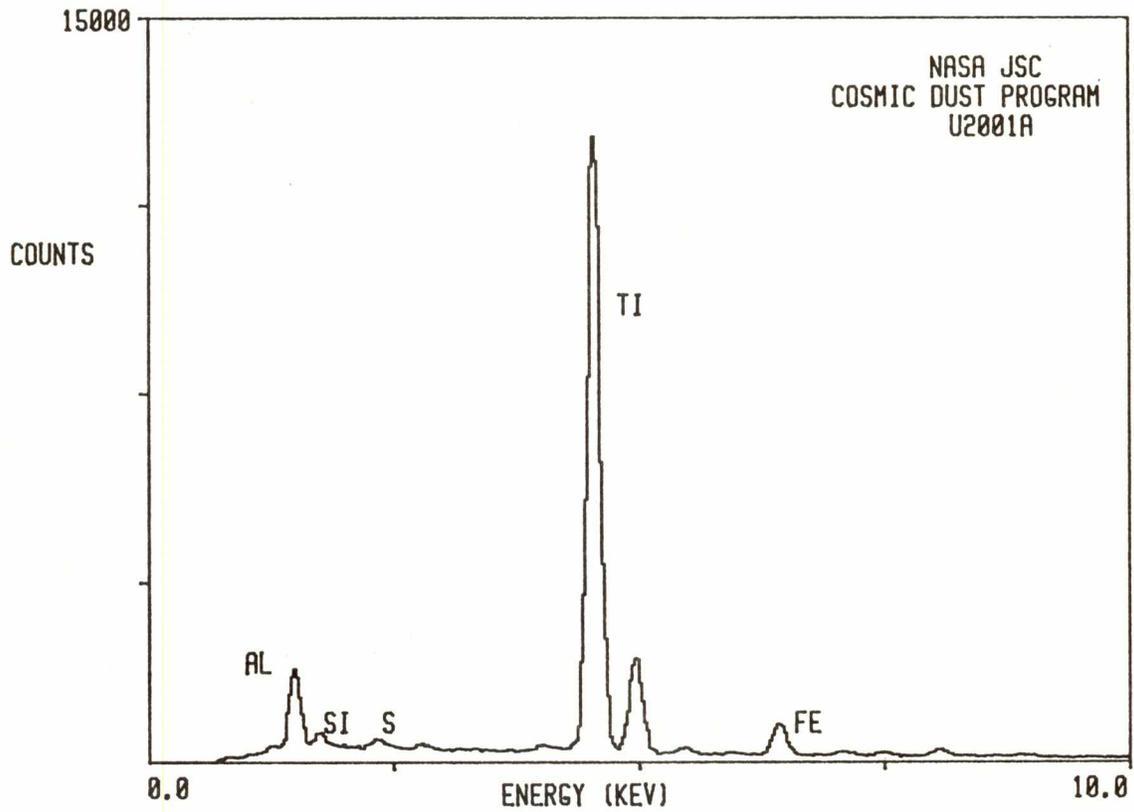
SIZE SHAPE TRANS.
4x5 I 0

COLOR LUSTER
Dk. Gray to Black D/SM

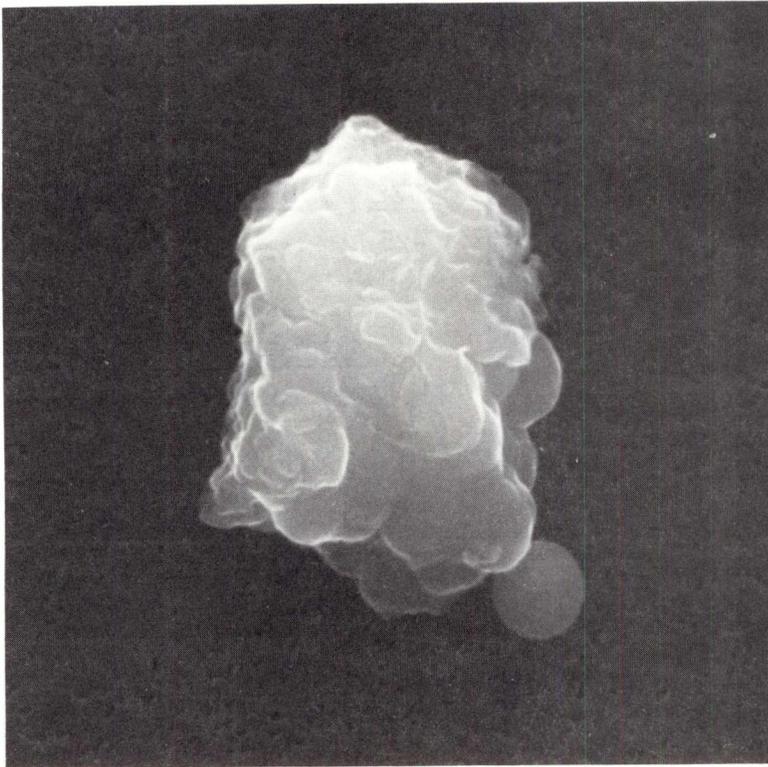
TYPE COMMENTS
TCA?

S-82-34561

U214A



U2001A15



SIZE
10x15

SHAPE
I

TRANS.
0

COLOR
Dk. Gray to Black

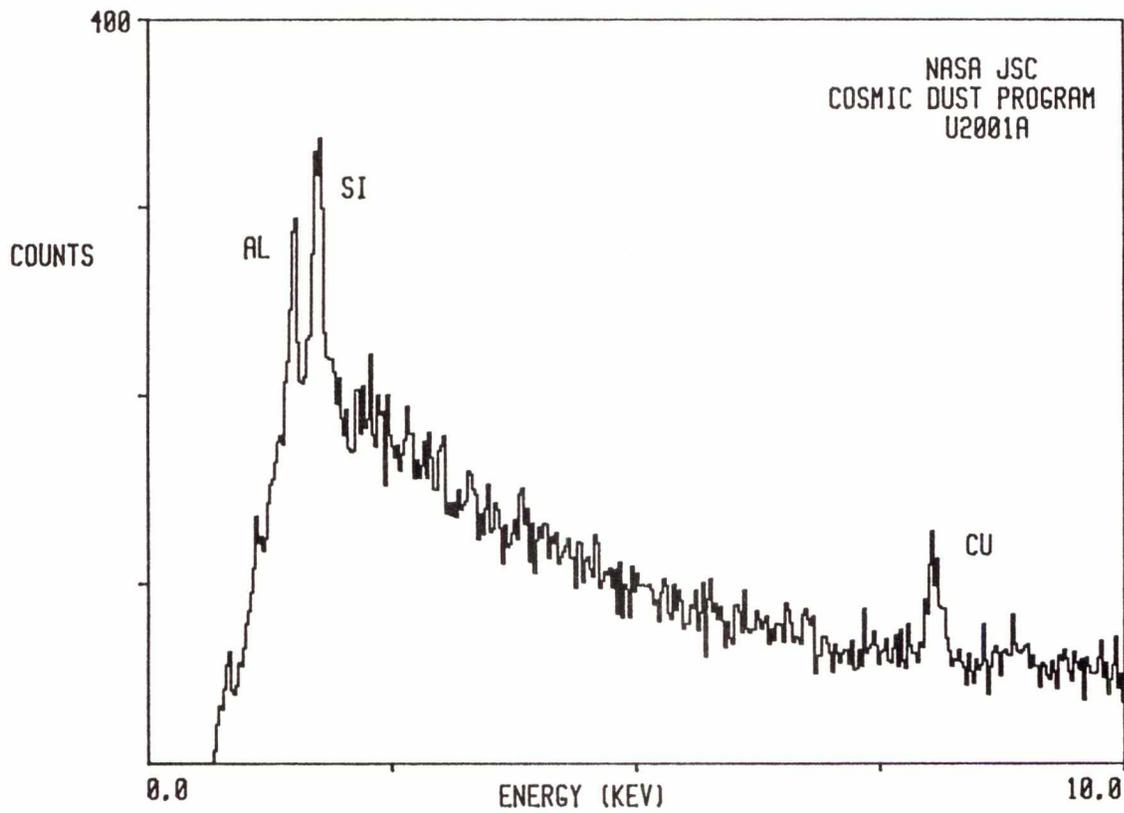
LUSTER
SM/M

TYPE
TCA?

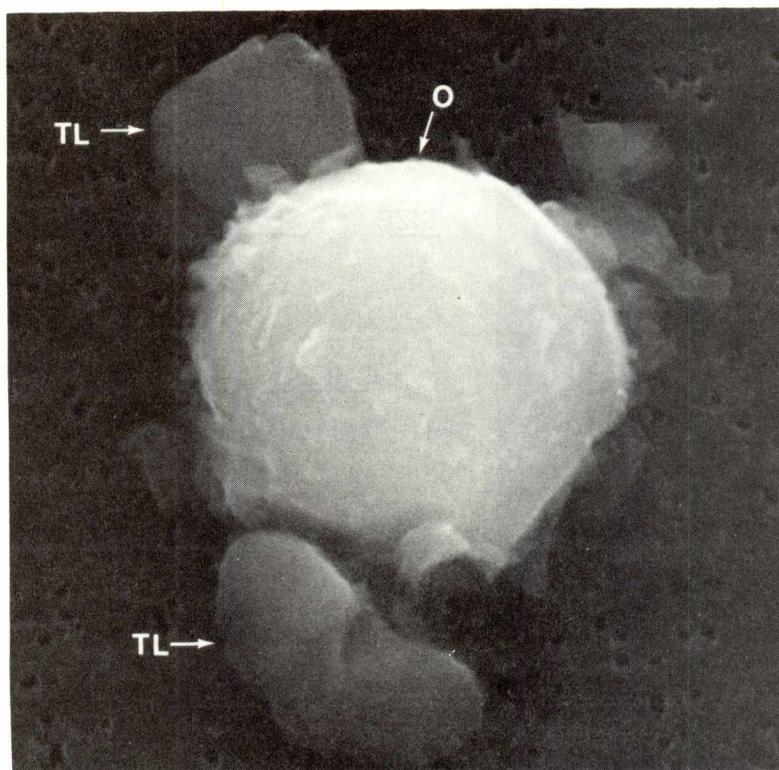
COMMENTS

S-82-34562

U215A



U2001A16



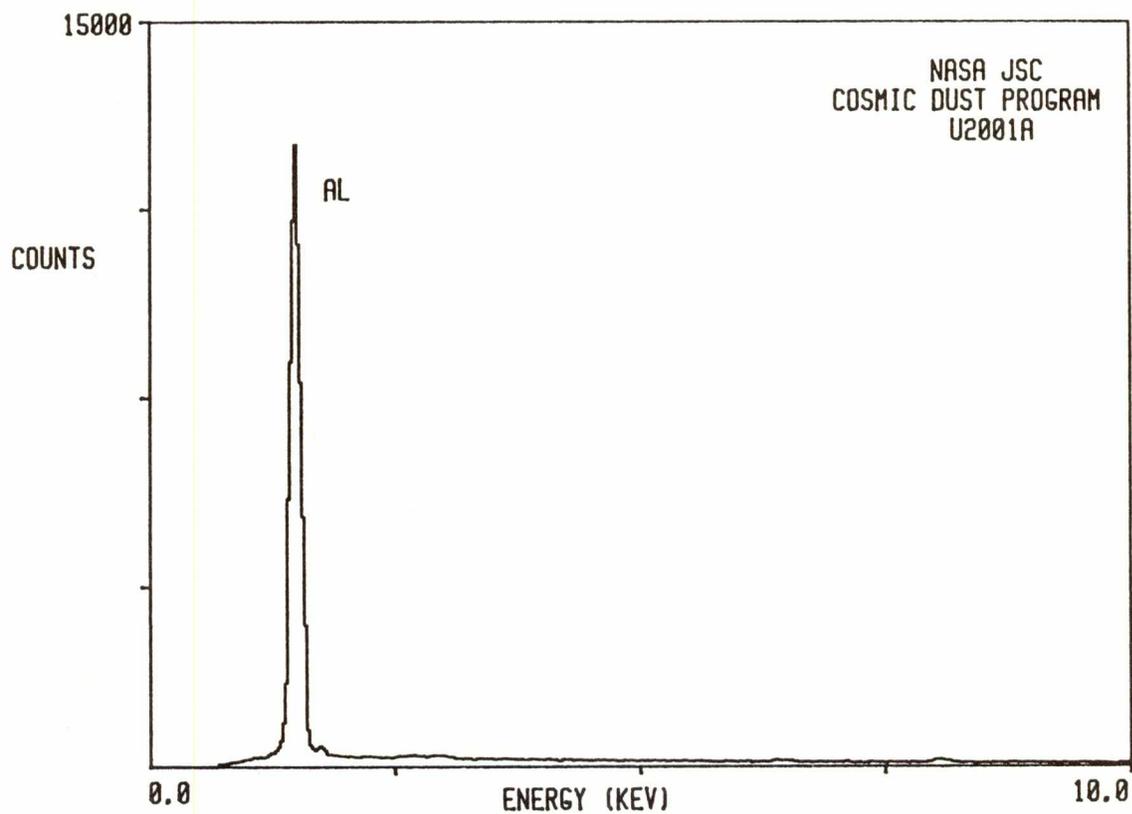
SIZE SHAPE TRANS.
10x15 I 0/TL

COLOR LUSTER
CL to Gray SV/V

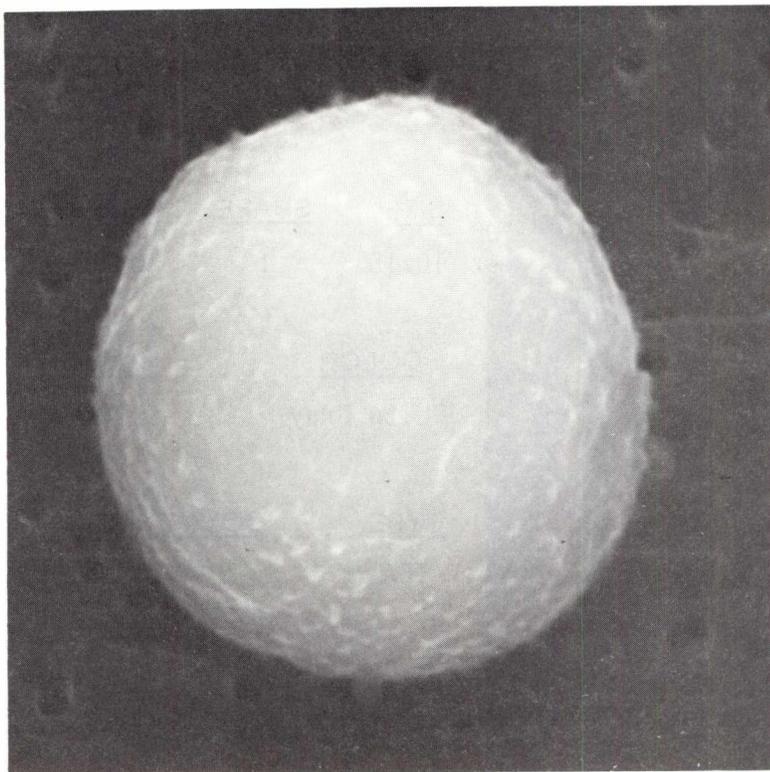
TYPE COMMENTS
TCA

S-82-34563

U216A



U2001A18



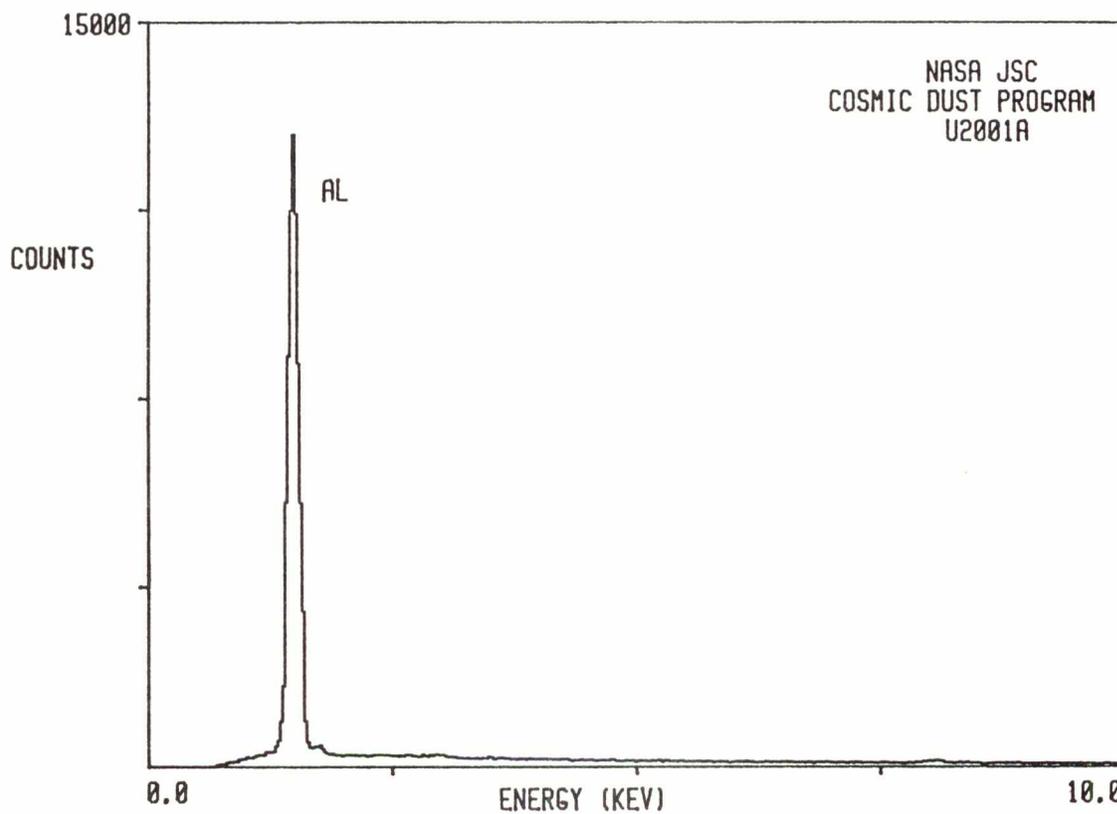
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
5	S	T

<u>COLOR</u>	<u>LUSTER</u>
Pale Yellow-Gray	V

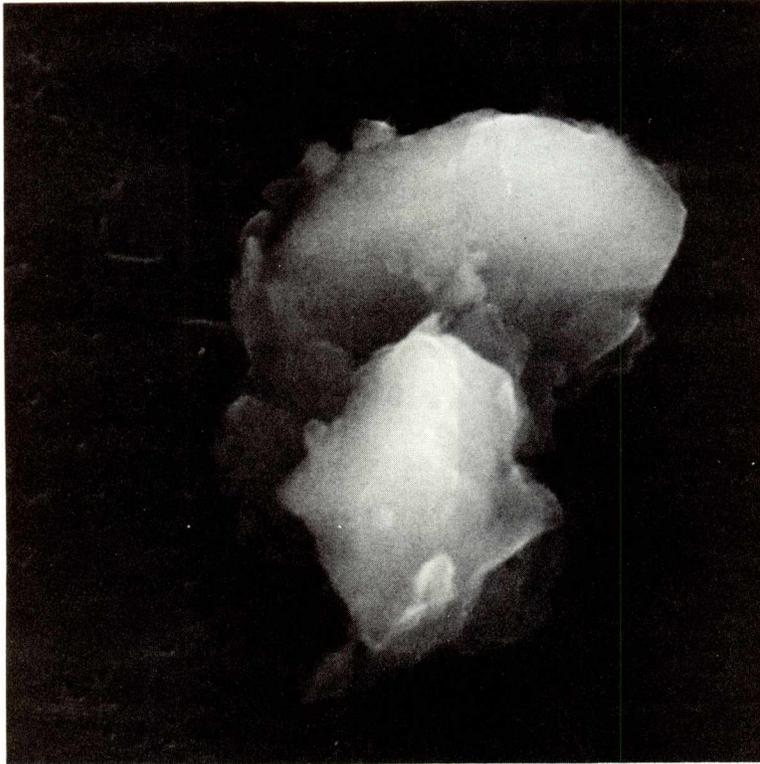
<u>TYPE</u>	<u>COMMENTS</u>
AOS	

U218A

S-82-34564



U2001A19



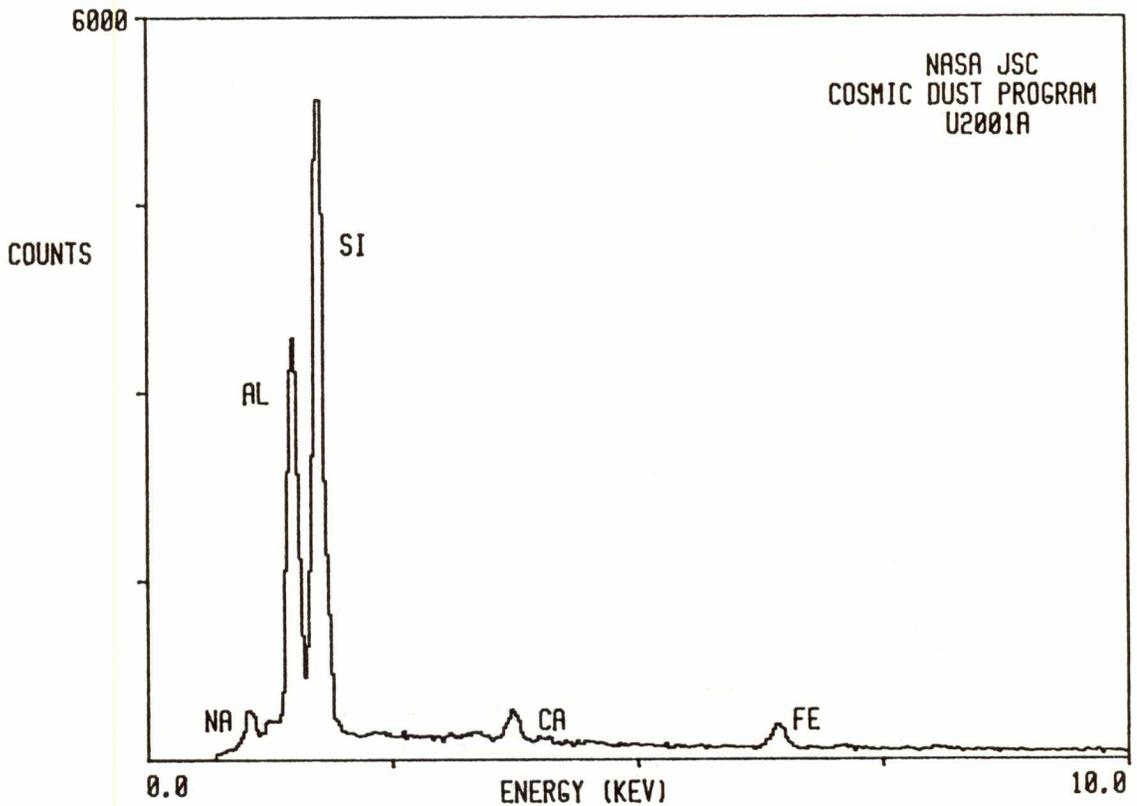
SIZE SHAPE TRANS.
9x11 I TL

COLOR LUSTER
Pale Yellow-Gray SV

TYPE COMMENTS
TCN Part of Al x-ray
 emission may be
 from Al grid on
 SEM mount

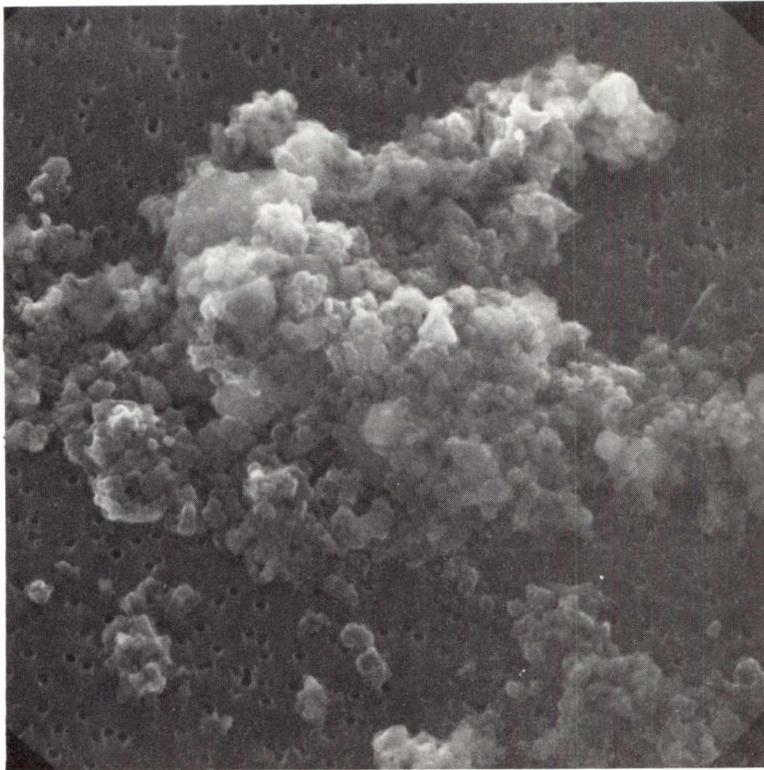
S-82-34565

U219A



MOUNT U2001B

U2001B1



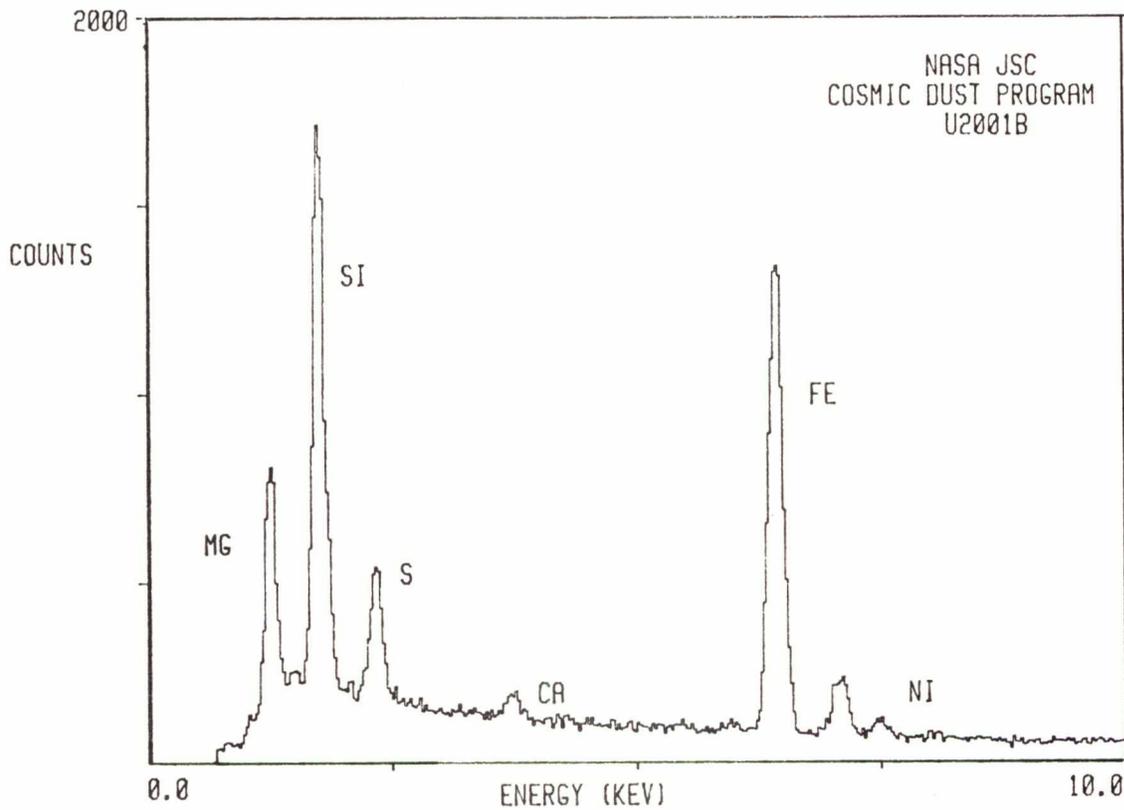
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
15x20	I	0

<u>COLOR</u>	<u>LUSTER</u>
Dk. Brown to Black	D/SV

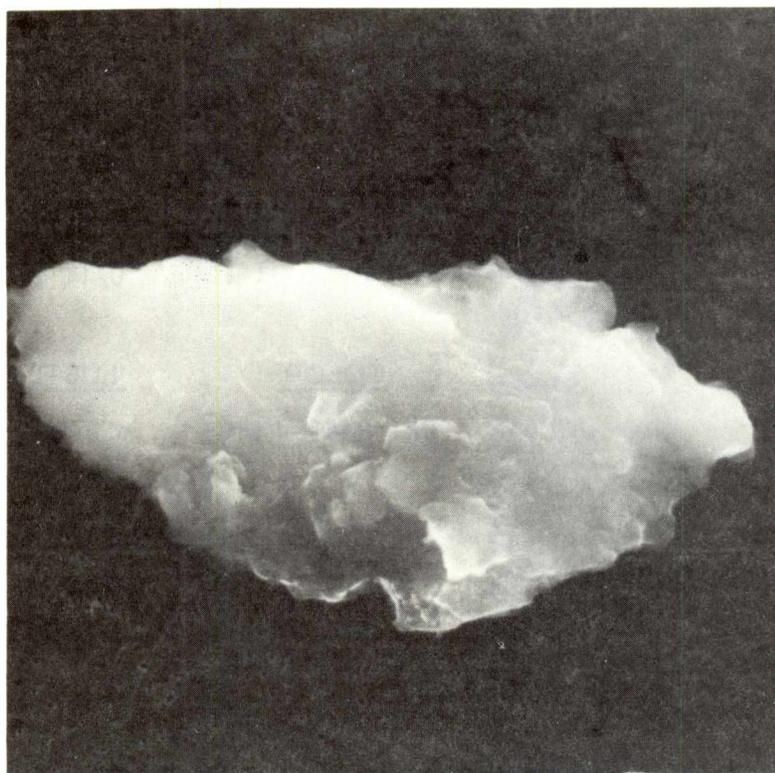
<u>TYPE</u>	<u>COMMENTS</u>
C	Numerous smaller fragments; some TL areas

U201B

S-82-35233



U2001B3



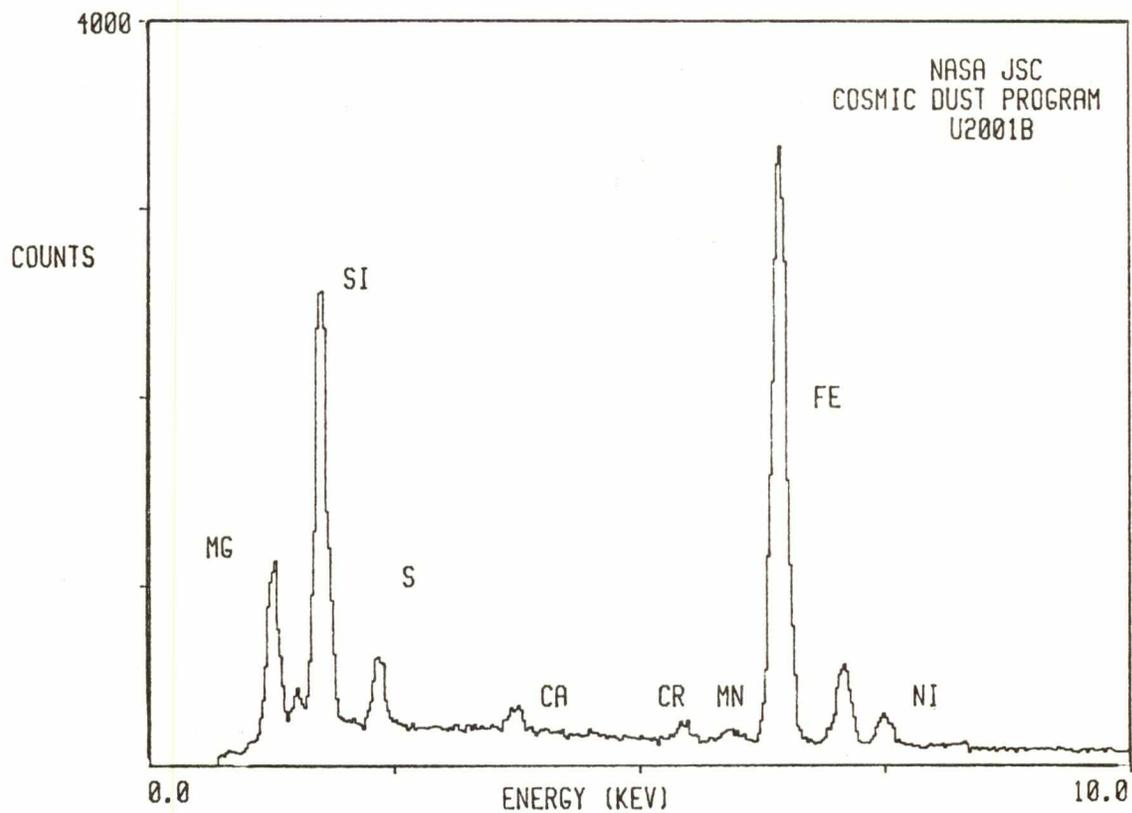
SIZE SHAPE TRANS.
18x36 I 0

COLOR LUSTER
Dk. Brown to Black SV

TYPE COMMENTS
C

S-82-35234

U203B



U2001B6



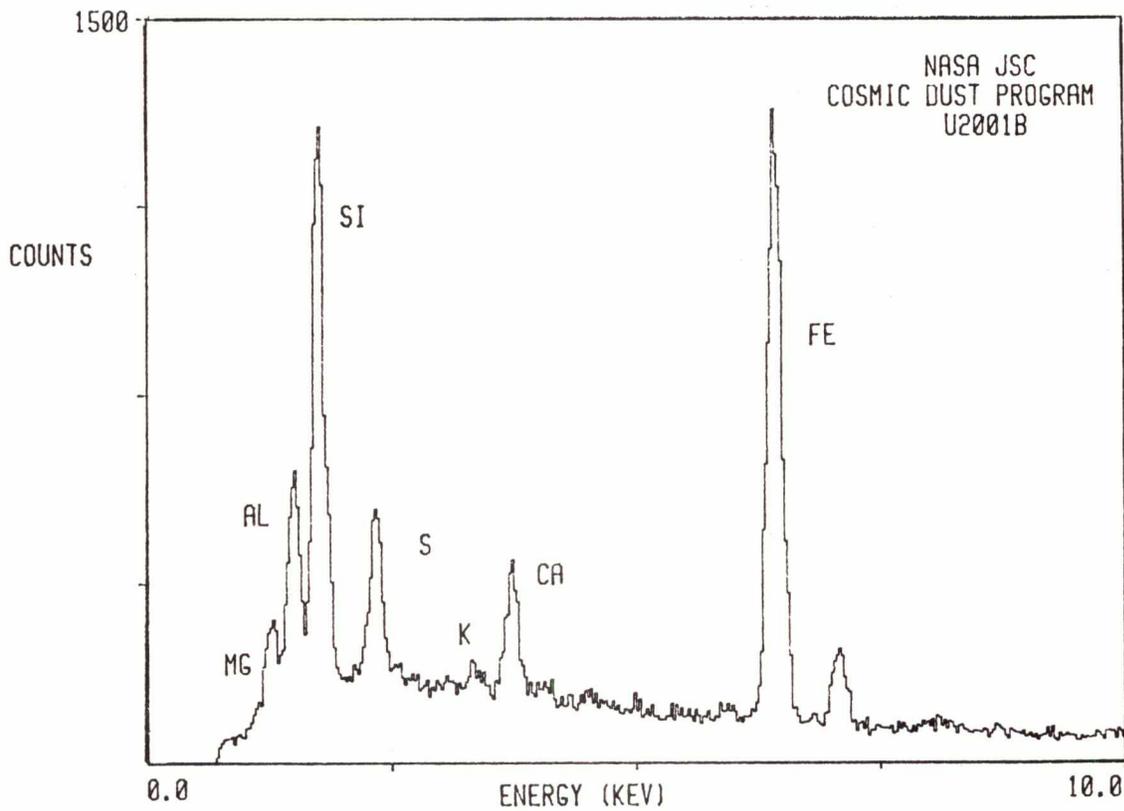
SIZE SHAPE TRANS.
25x28 I 0/TL

COLOR LUSTER
Dk. Red-Brown D/SV

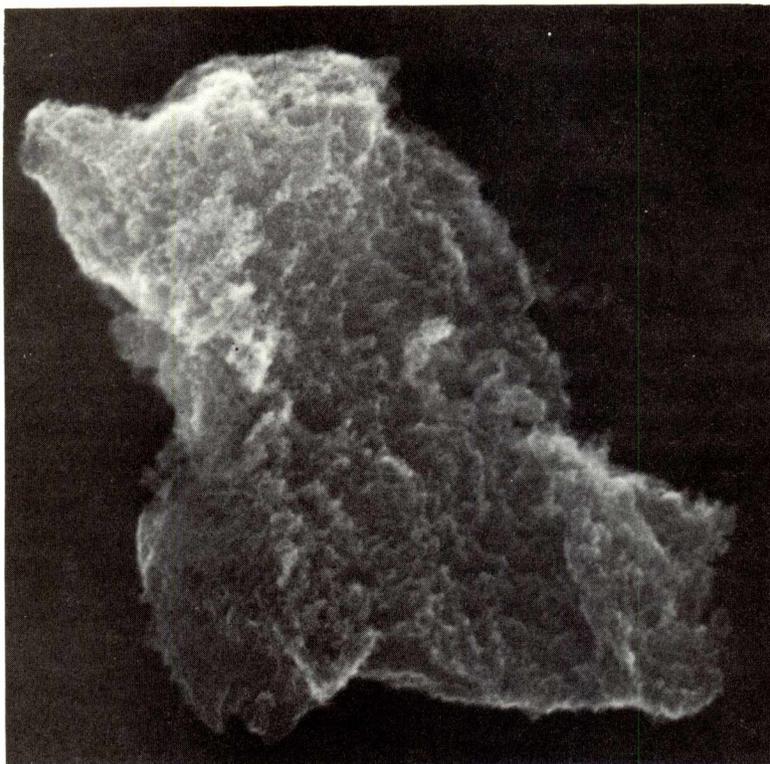
TYPE COMMENTS
C?

U206B

S-82-35235



U2001B7



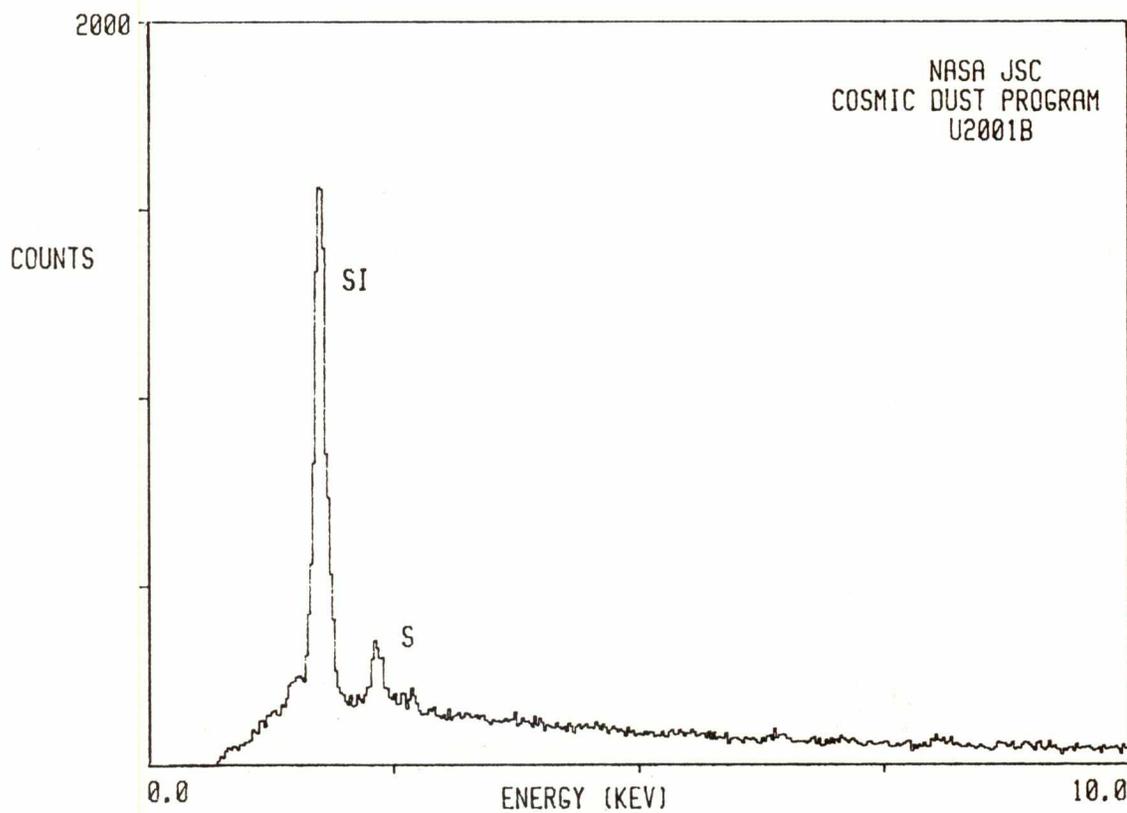
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
28x44	I	0

<u>COLOR</u>	<u>LUSTER</u>
Dk. Brown to Black	D

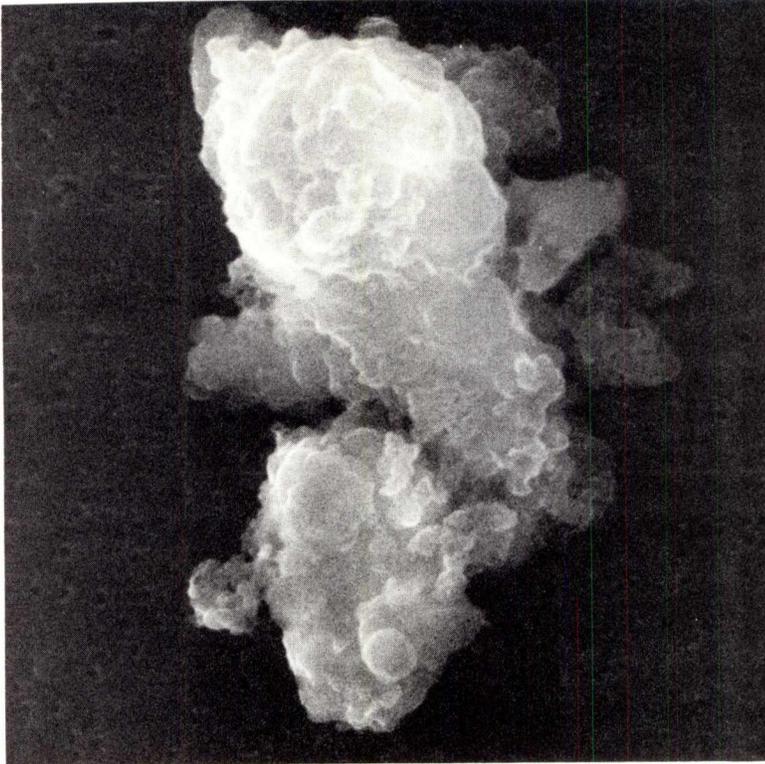
<u>TYPE</u>	<u>COMMENTS</u>
TCN?	

S-82-35236

U207B



U2001B8



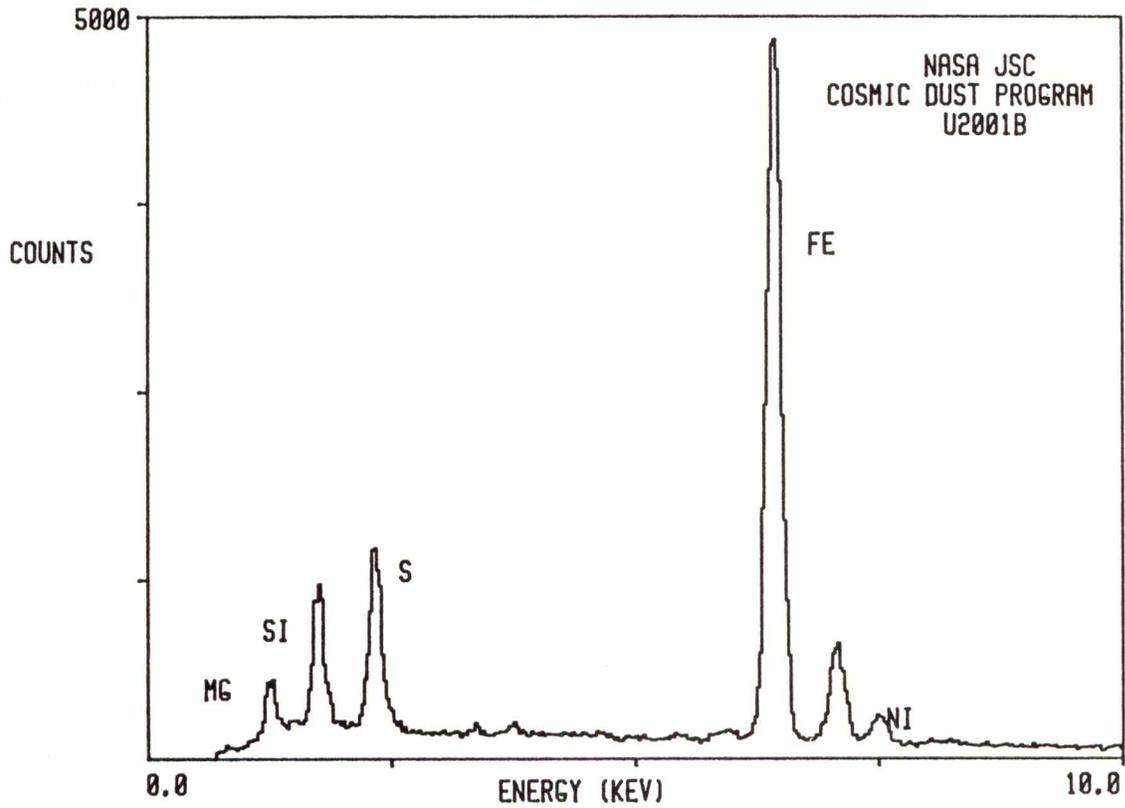
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
13x19	I	0

<u>COLOR</u>	<u>LUSTER</u>
Dk. Brown to Black	SV

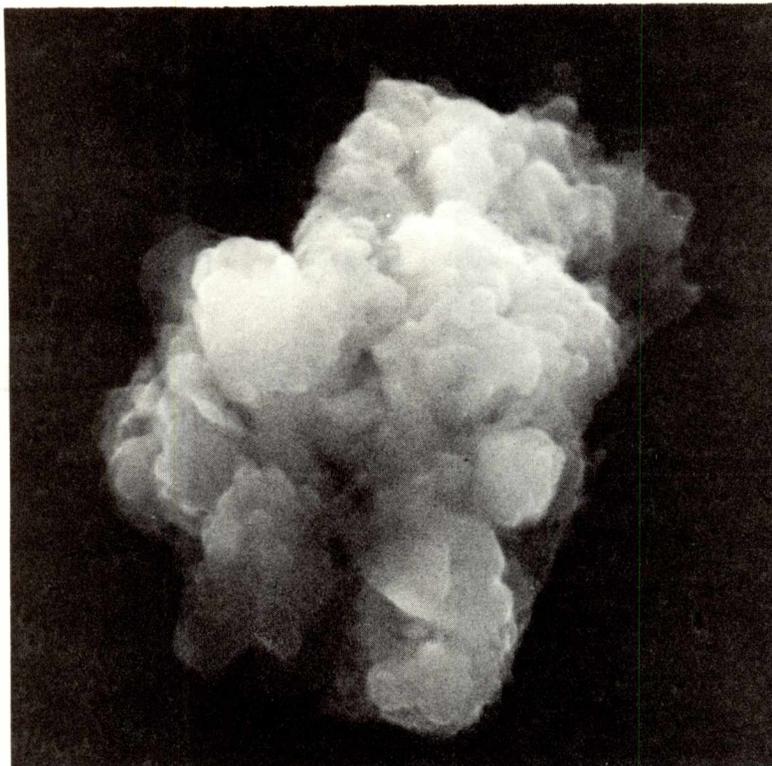
<u>TYPE</u>	<u>COMMENTS</u>
C	Smaller fragments nearby

U2088

S-82-35237



U2001B9



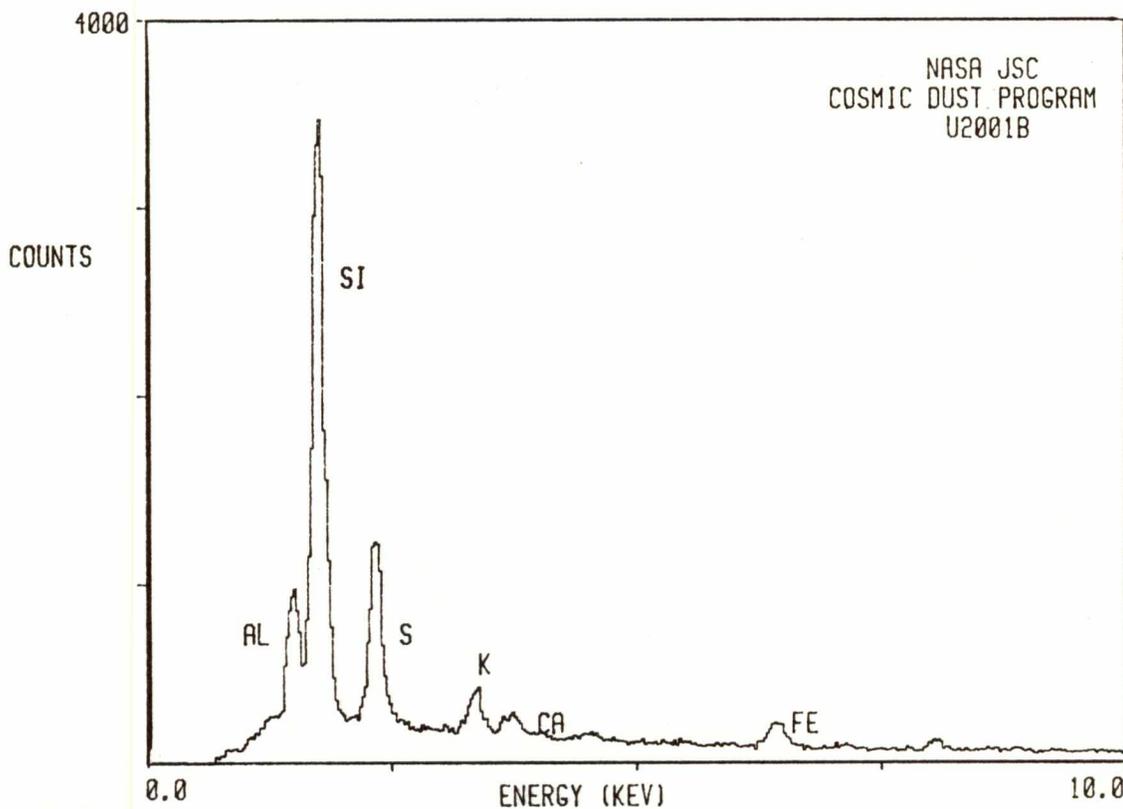
SIZE SHAPE TRANS.
14x20 I 0

COLOR LUSTER
Black SV

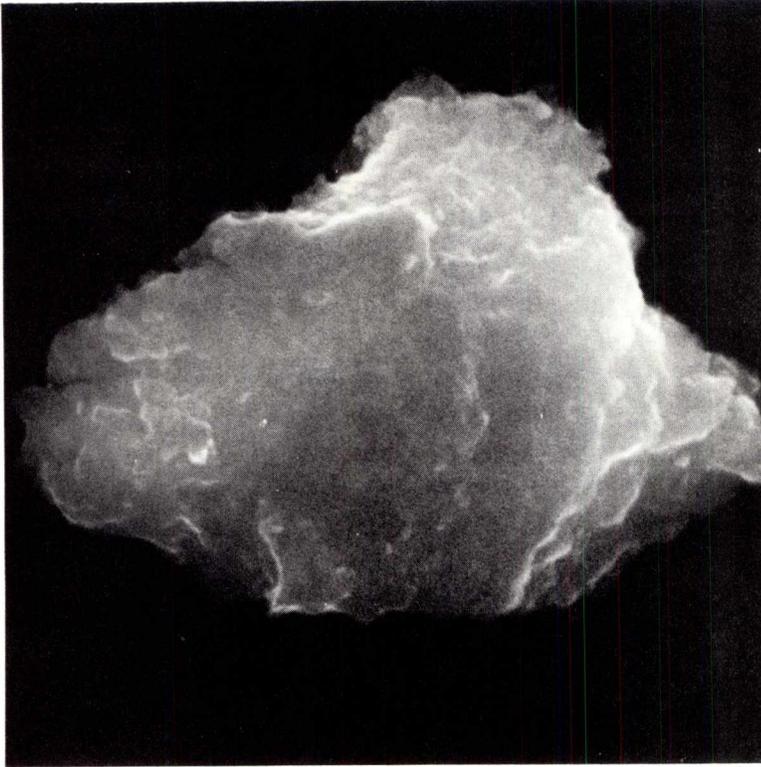
TYPE COMMENTS
TCN?

S-82-35238

U209B



U2001B10



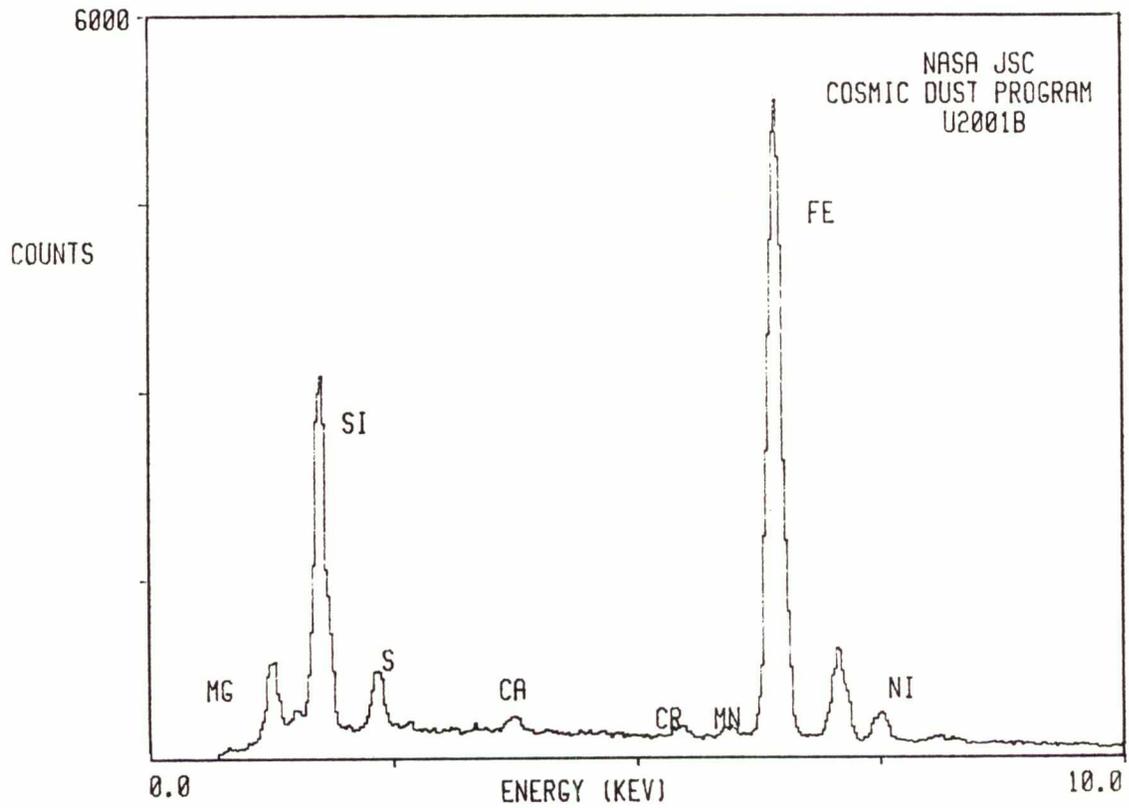
SIZE SHAPE TRANS.
19x27 I 0

COLOR LUSTER
Dk. Brown to Black SV

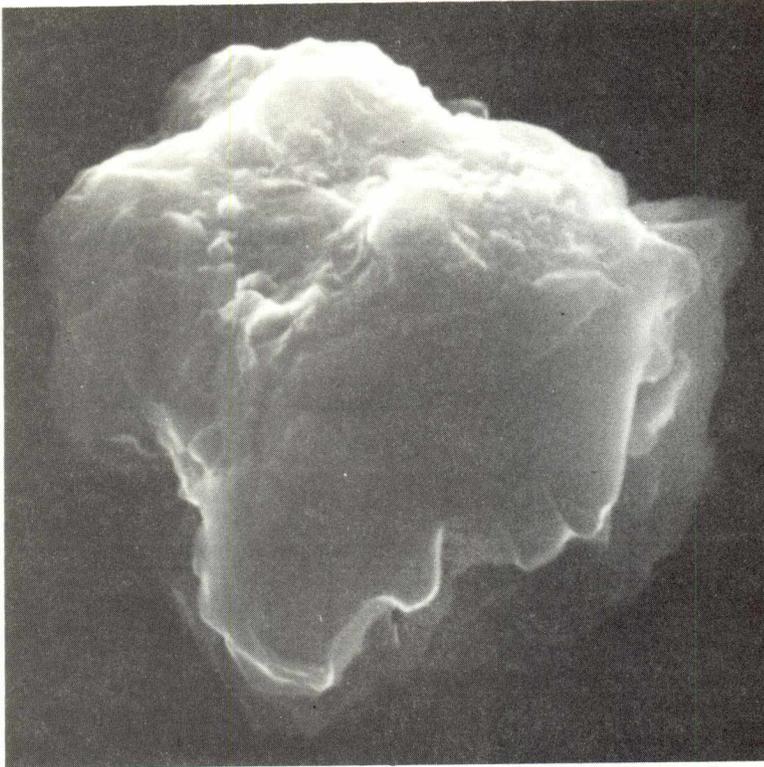
TYPE COMMENTS
C

U210B

S-82-35239



U2001B11



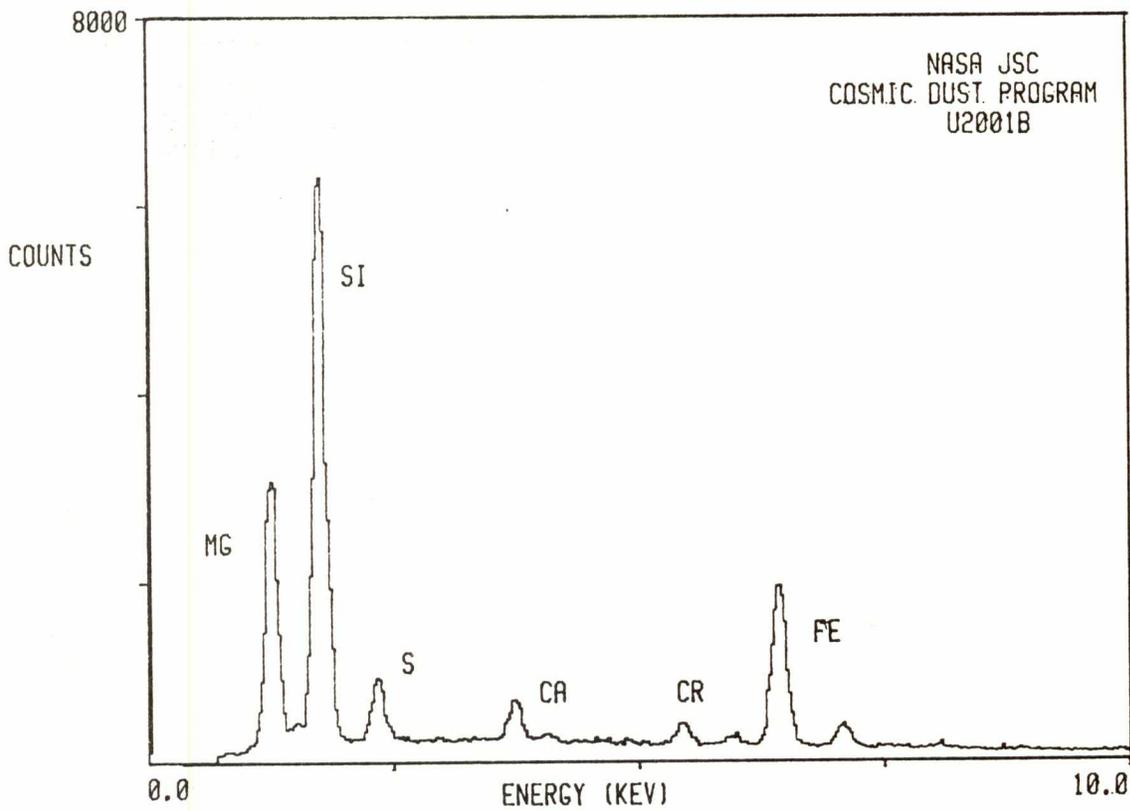
SIZE SHAPE TRANS.
22x24 I 0/TL

COLOR LUSTER
Gray to Black SV

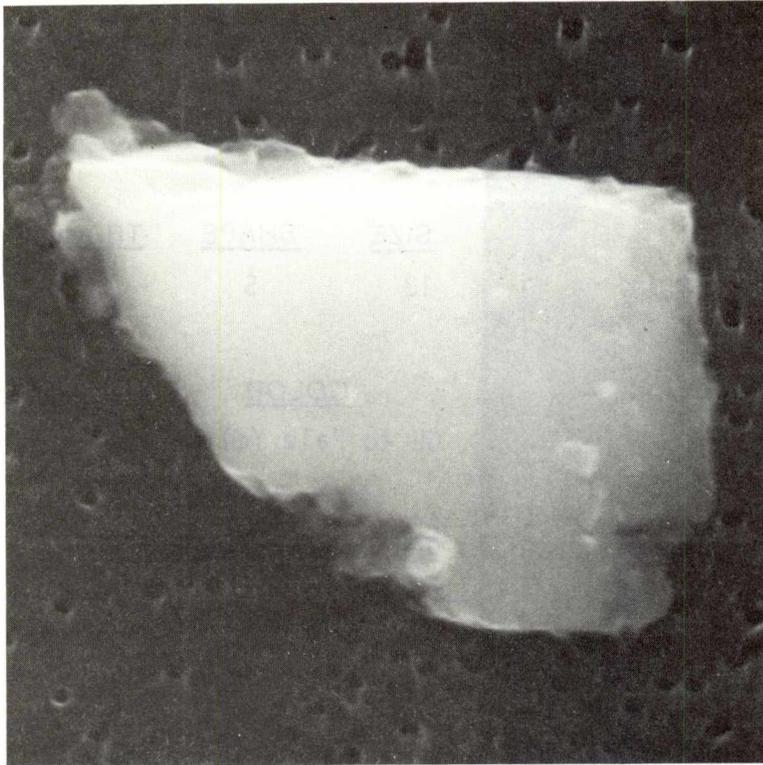
TYPE COMMENTS
C? Conglomeration
of TL and O
phases

S-82-35240

U211B



U2001B13



SIZE
7x9

SHAPE
I

TRANS.
T

COLOR
CL to Pale Gray

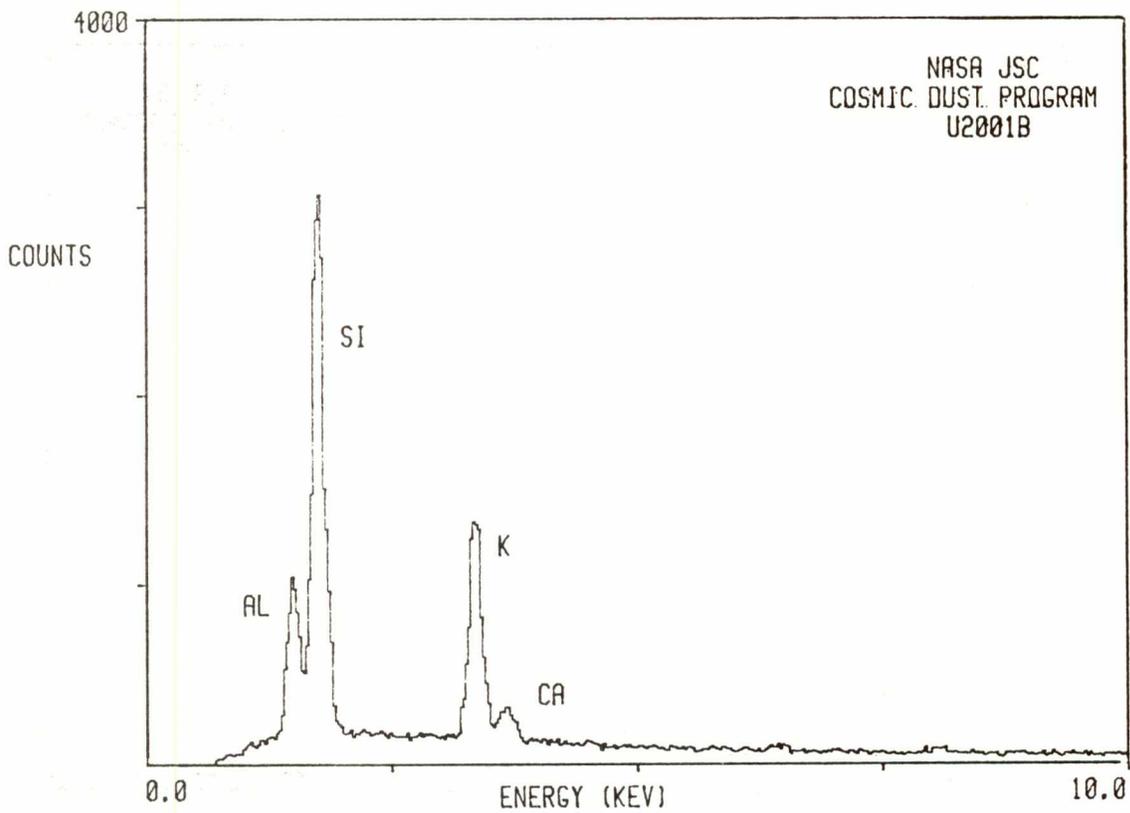
LUSTER
V

TYPE
TCN

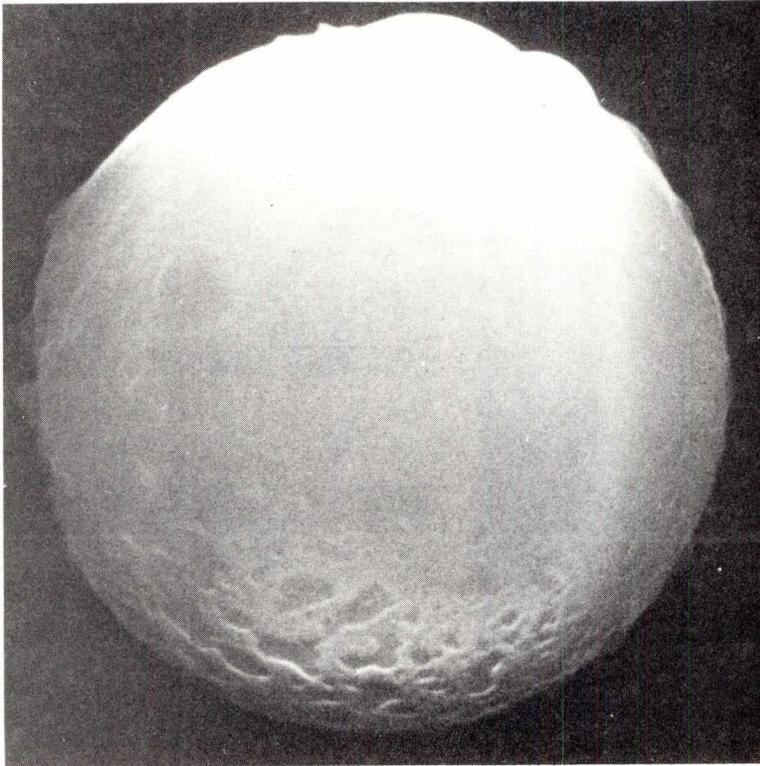
COMMENTS
Associated with
U2001B12

S-82-35242

U213B



U2001B14



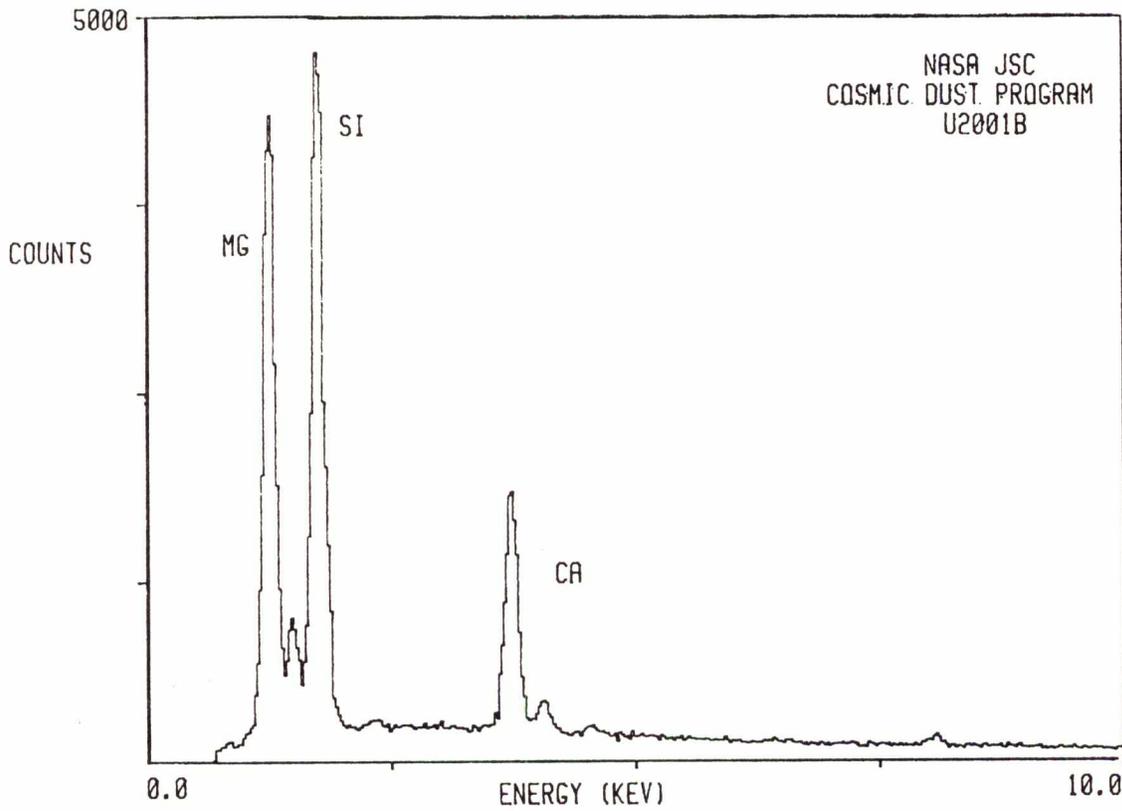
U214B

S-82-35243

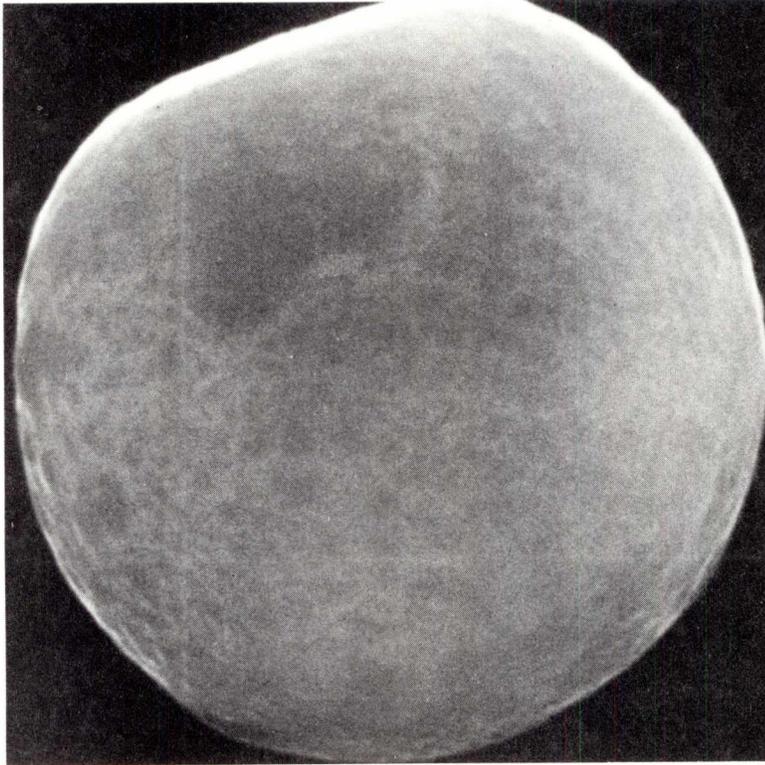
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
13	S	T

<u>COLOR</u>	<u>LUSTER</u>
CL to Pale Yellow	V

<u>TYPE</u>	<u>COMMENTS</u>
C?	



U2001B16



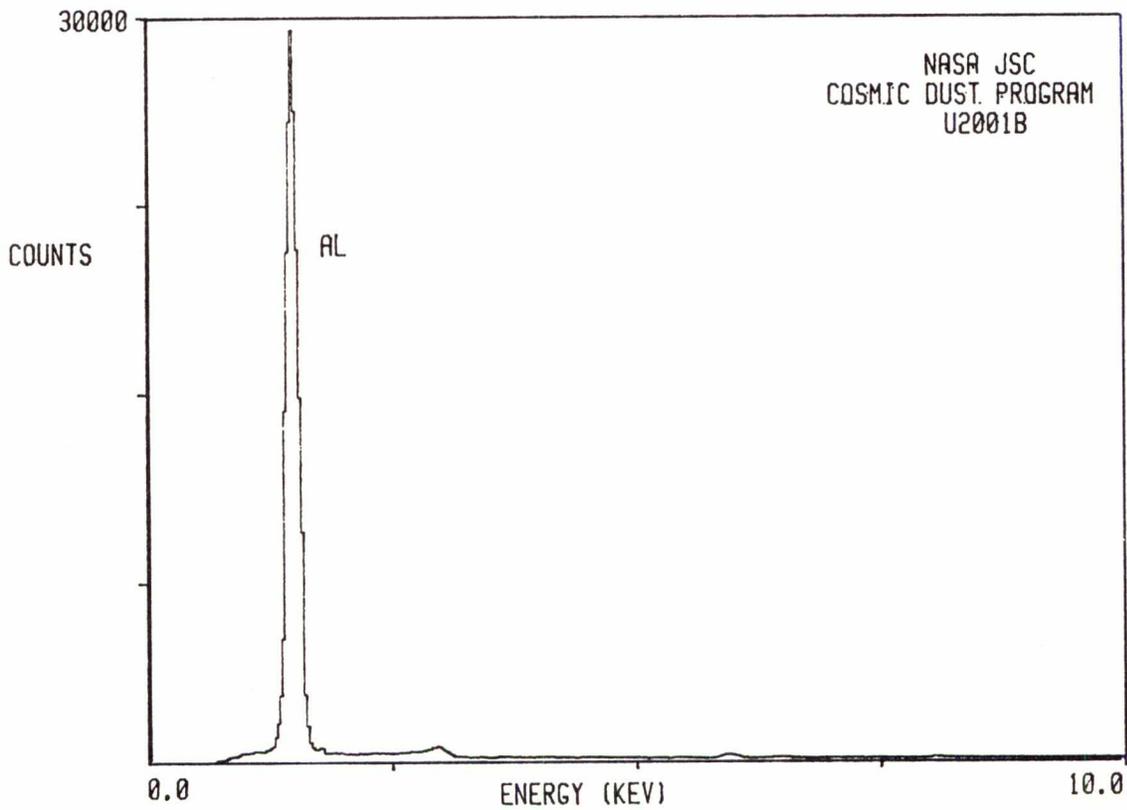
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
15	S	0

<u>COLOR</u>	<u>LUSTER</u>
Steel Gray	M

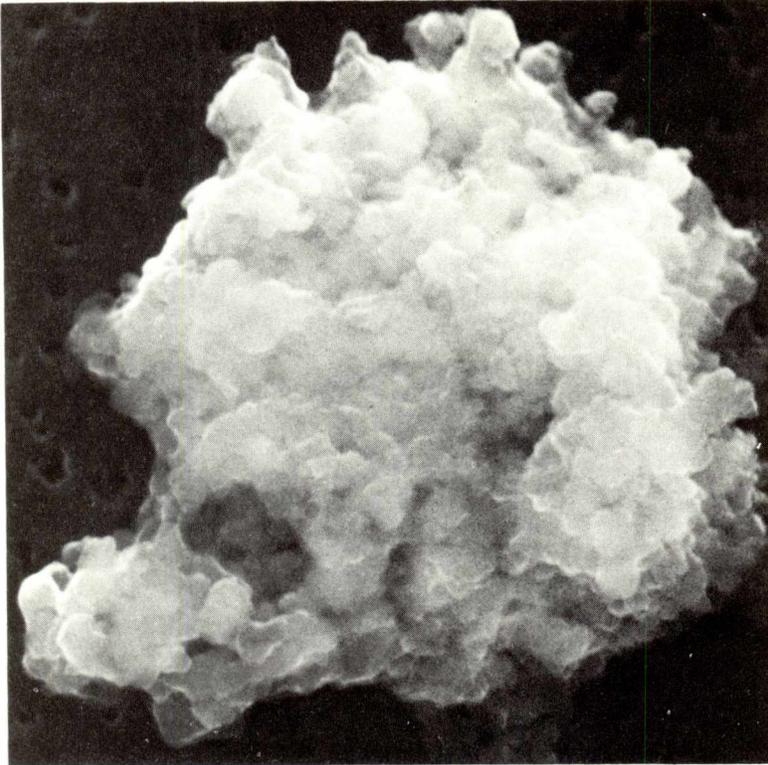
<u>TYPE</u>	<u>COMMENTS</u>
TCA	

S-82-35245

U216B



U2001B17



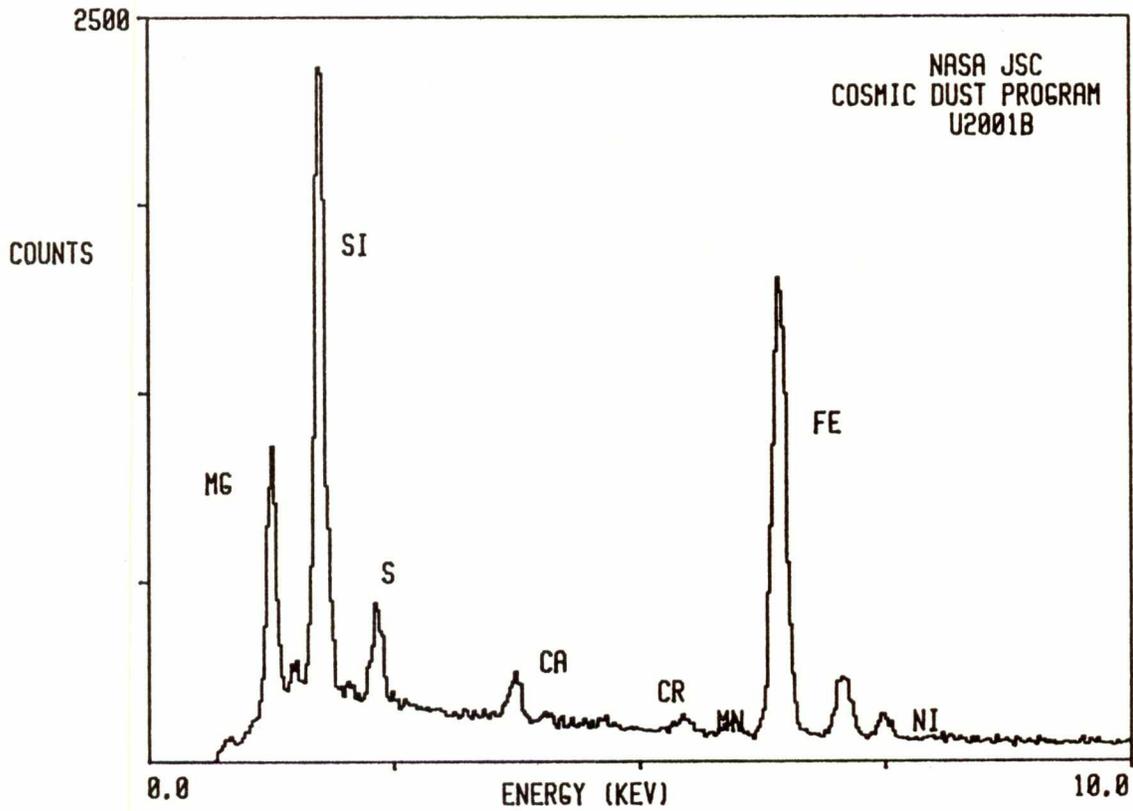
SIZE SHAPE TRANS.
11x12 I 0

COLOR LUSTER
Dk. Gray to Black D/SV

TYPE COMMENTS
C

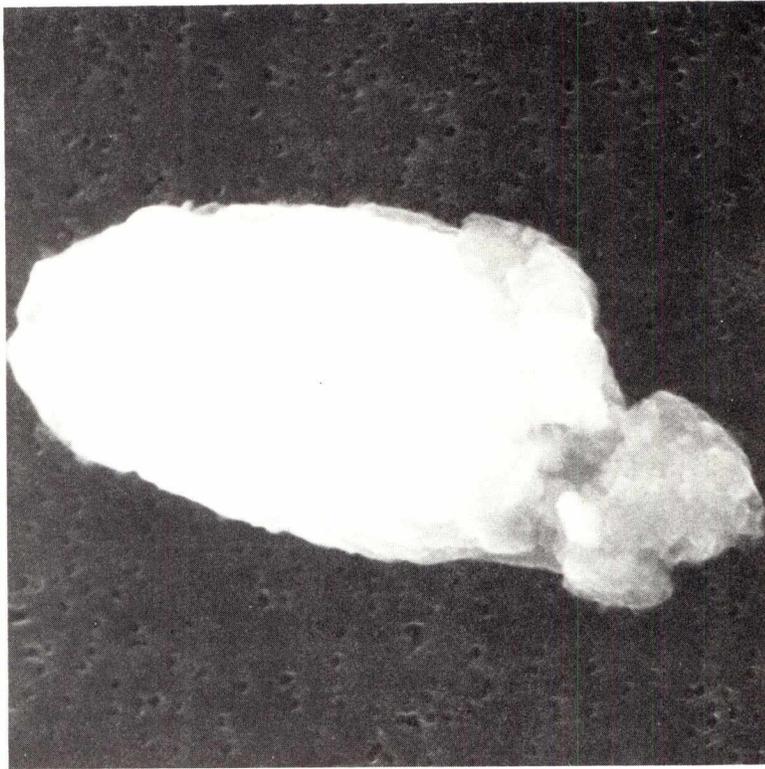
S-82-35246

U217B



MOUNT U2001C

U2001C1



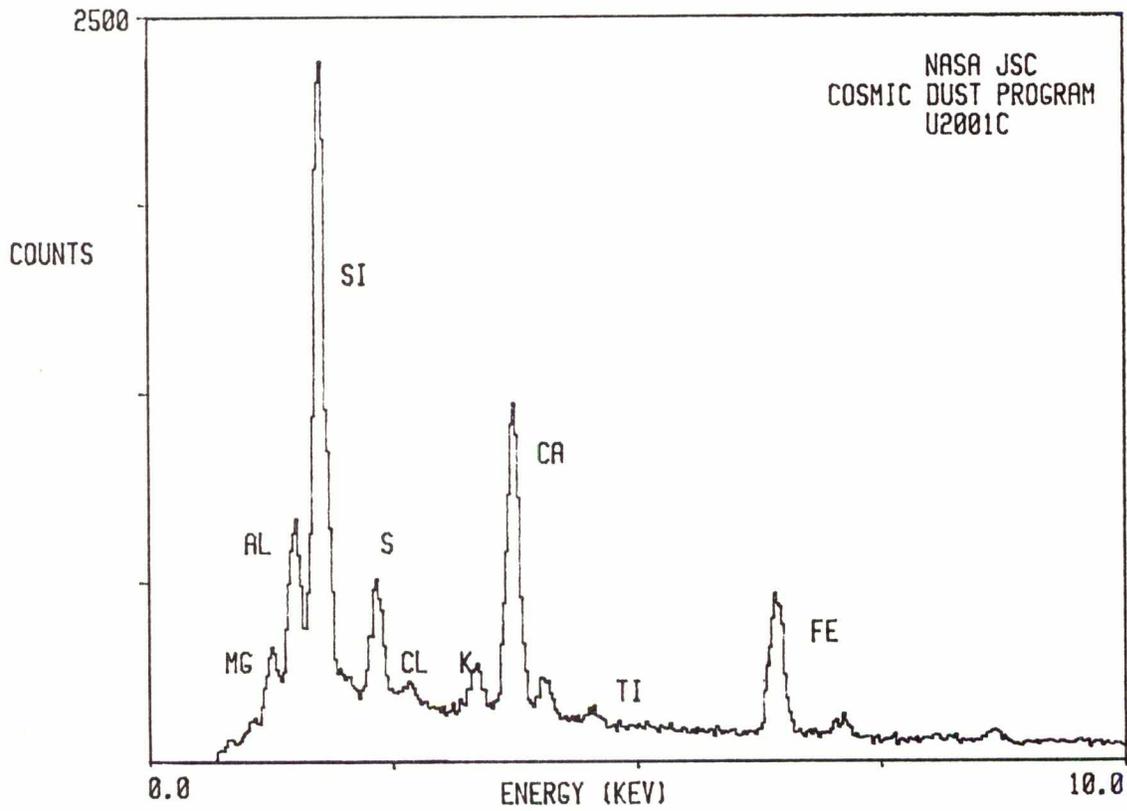
SIZE SHAPE TRANS.
9x20 I 0

COLOR LUSTER
Dk. Gray to Black SM

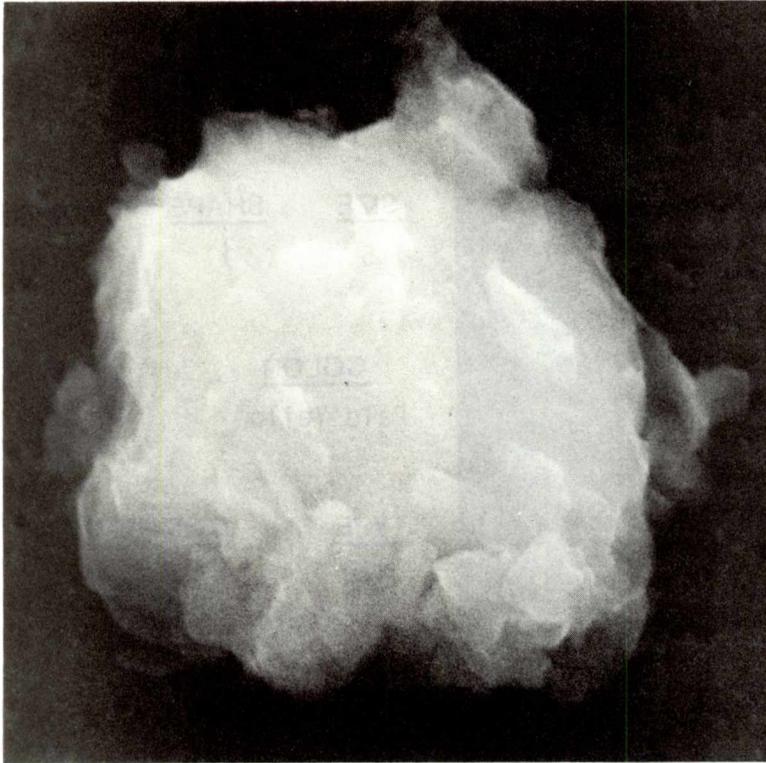
TYPE COMMENTS
TCN

U201C

S-82-35215



U2001C2



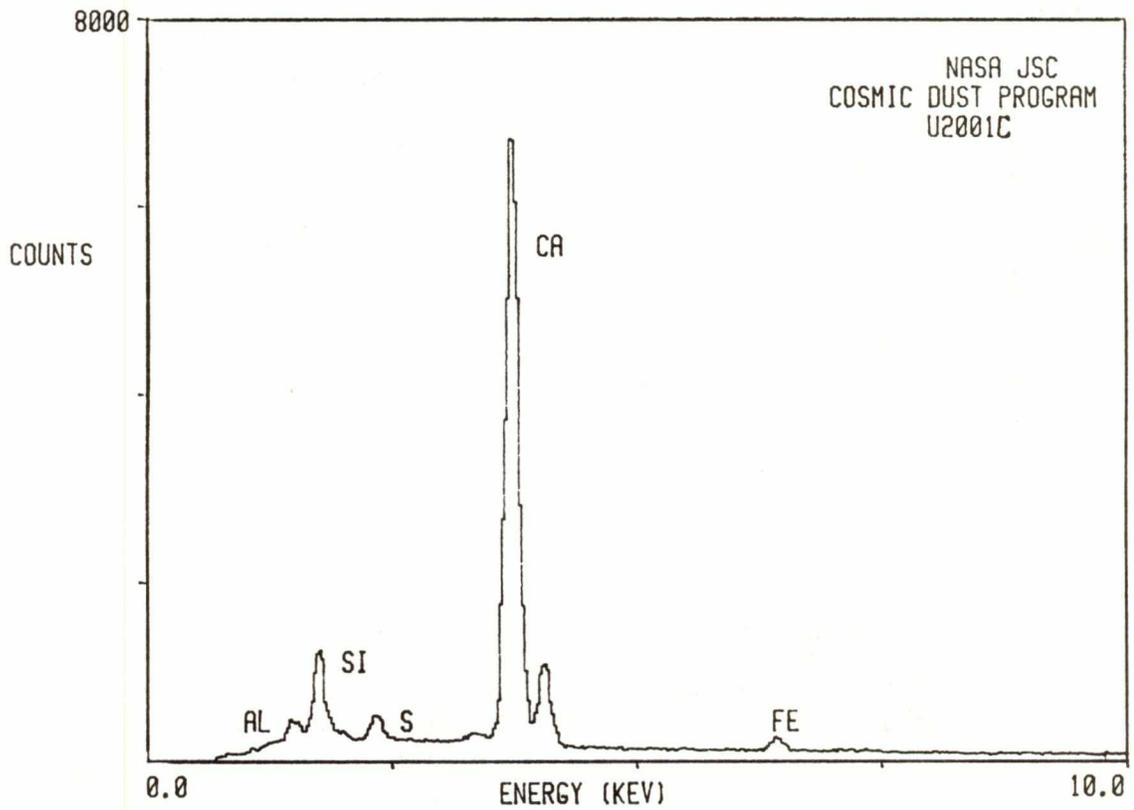
SIZE SHAPE TRANS.
12 E TL

COLOR LUSTER
Pale Yellow-Gray SV

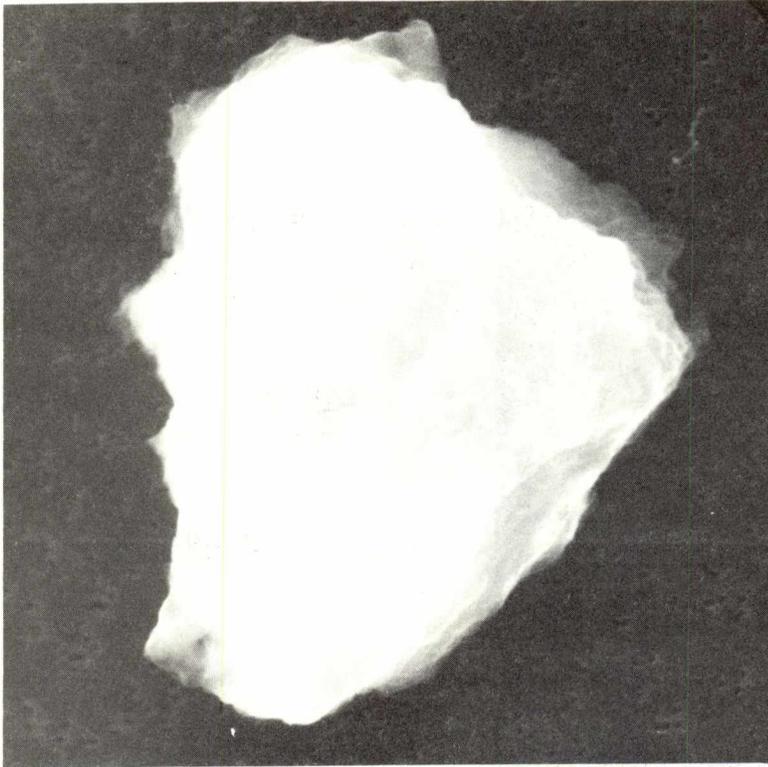
TYPE COMMENTS
?

S-82-35216

U202C



U2001C4



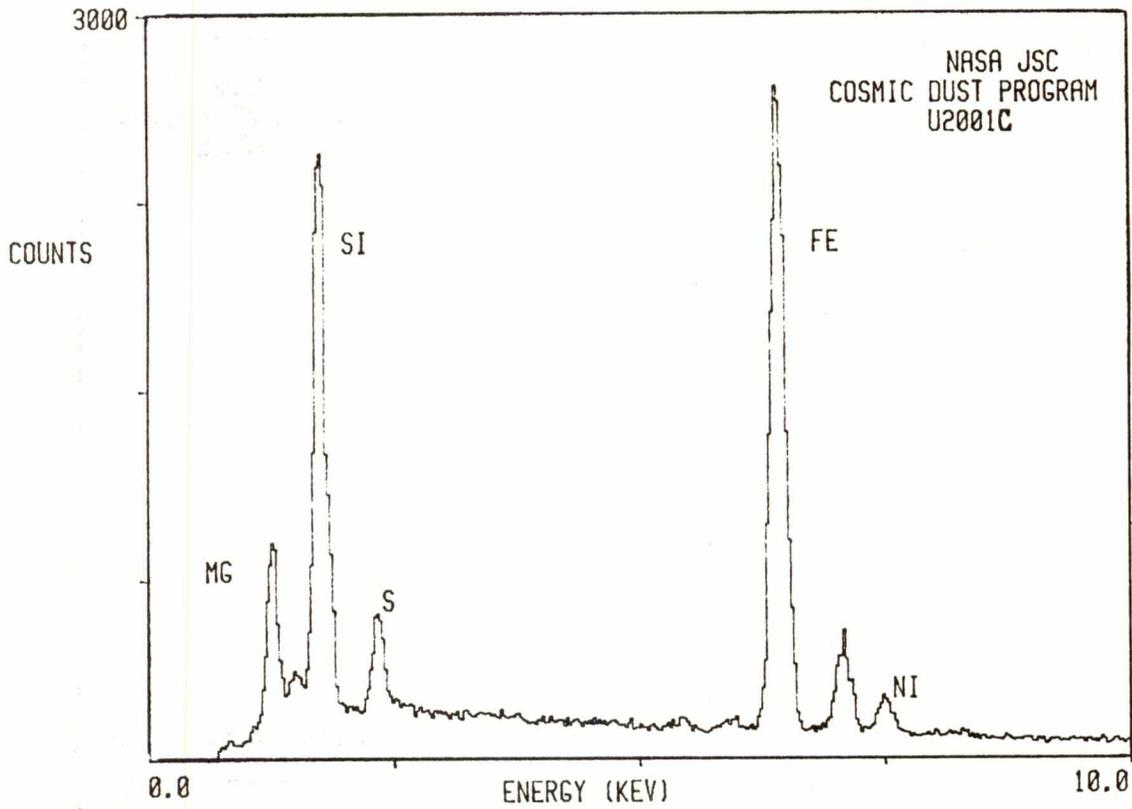
SIZE SHAPE TRANS.
18x22 I 0

COLOR LUSTER
Dk. Brown to Black D/SV

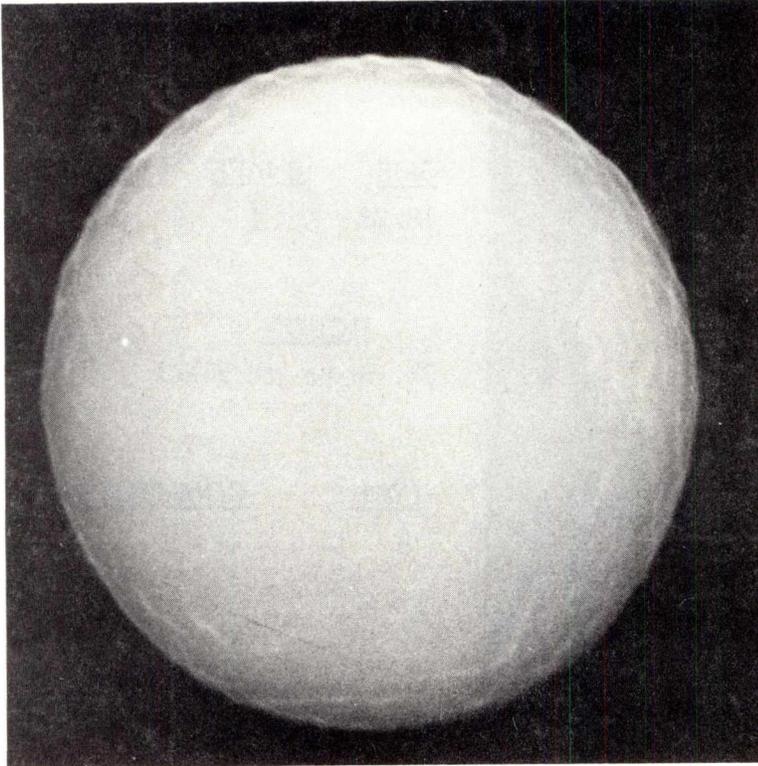
TYPE COMMENTS
C

S-82-35218

U204C



U2001C5



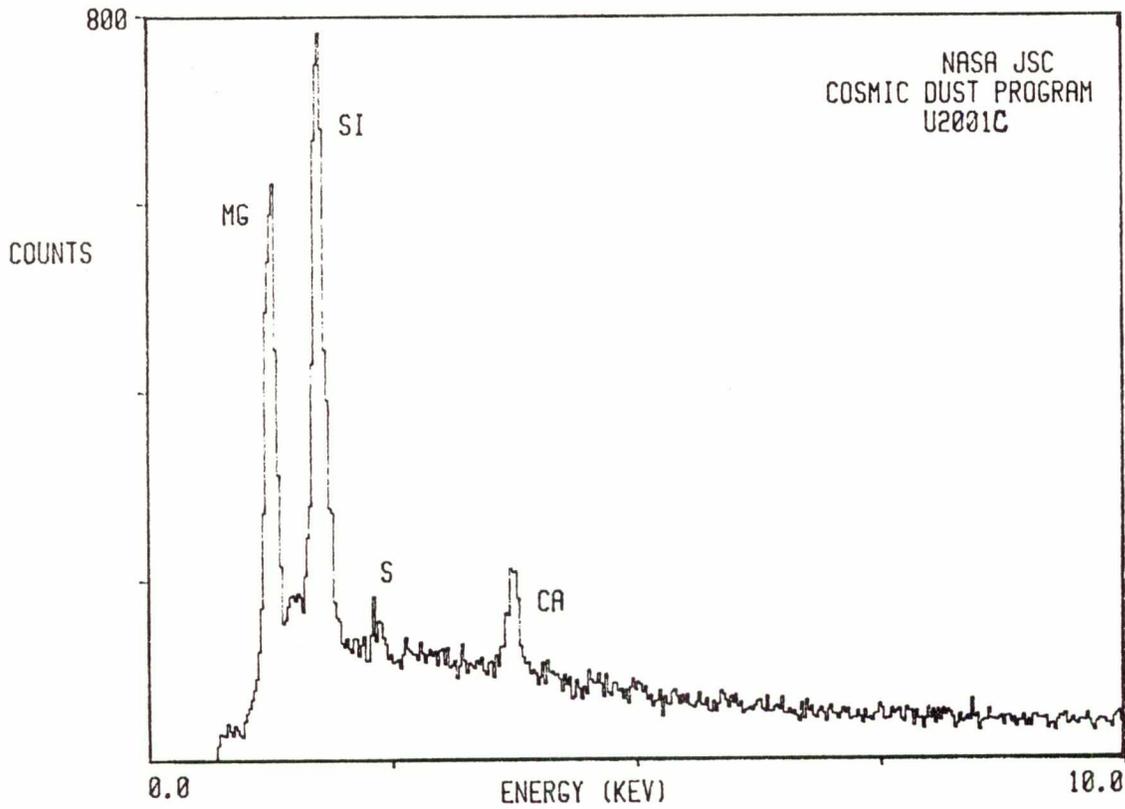
SIZE SHAPE TRANS.
9 S T

COLOR LUSTER
CL to Pale Yellow V

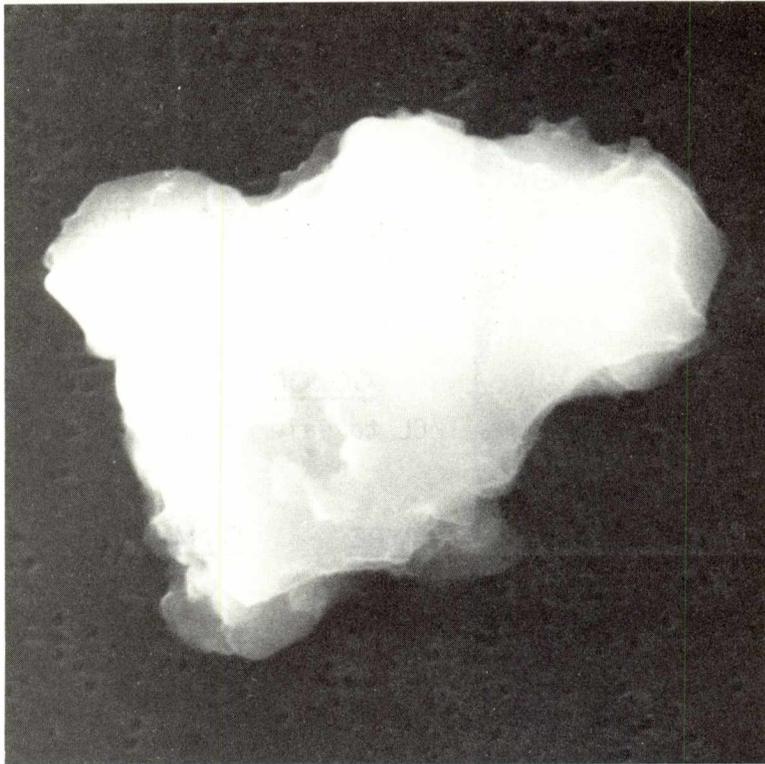
TYPE COMMENTS
C??

U205C

S-82-35219



U2001C6



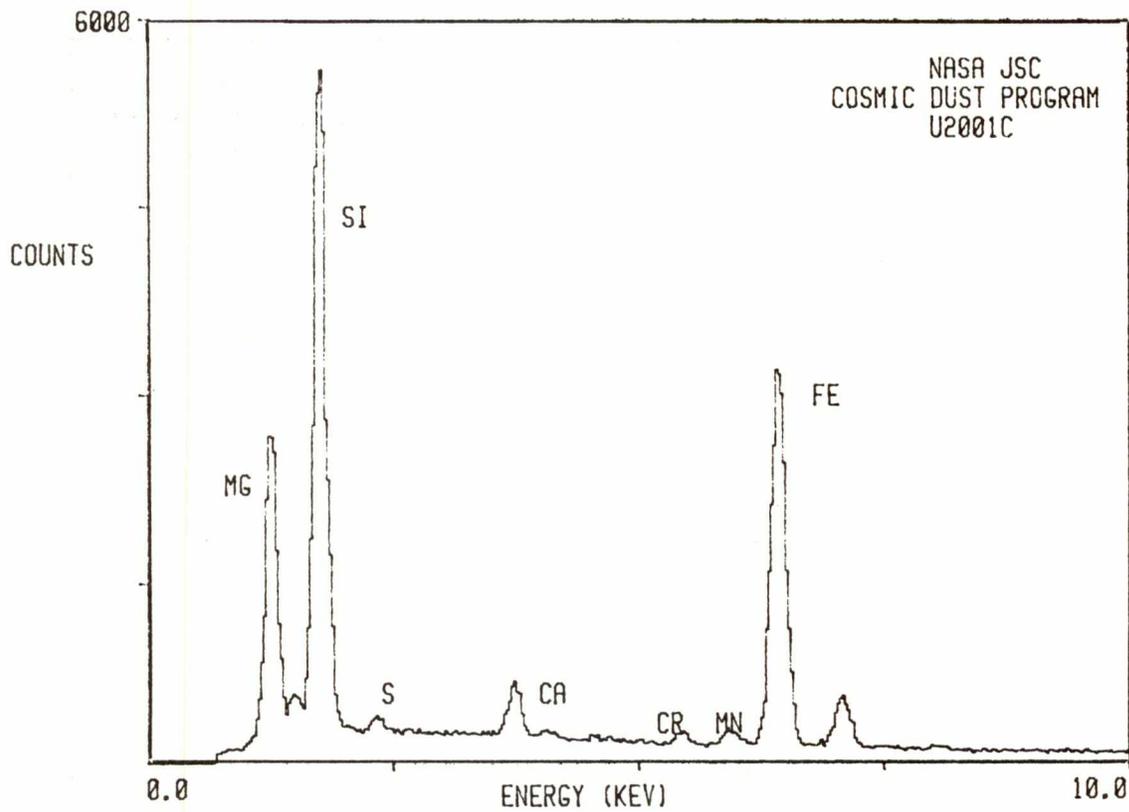
SIZE SHAPE TRANS.
11x14 I TL

COLOR LUSTER
Pale Yellow-Gray SV

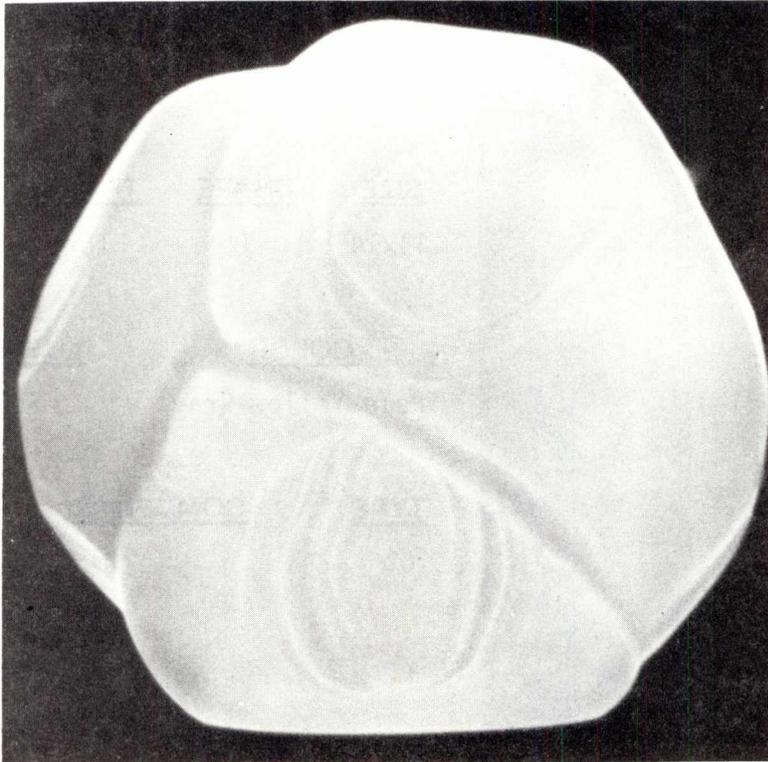
TYPE COMMENTS
C?

U206C

S-82-35220



U2001C7



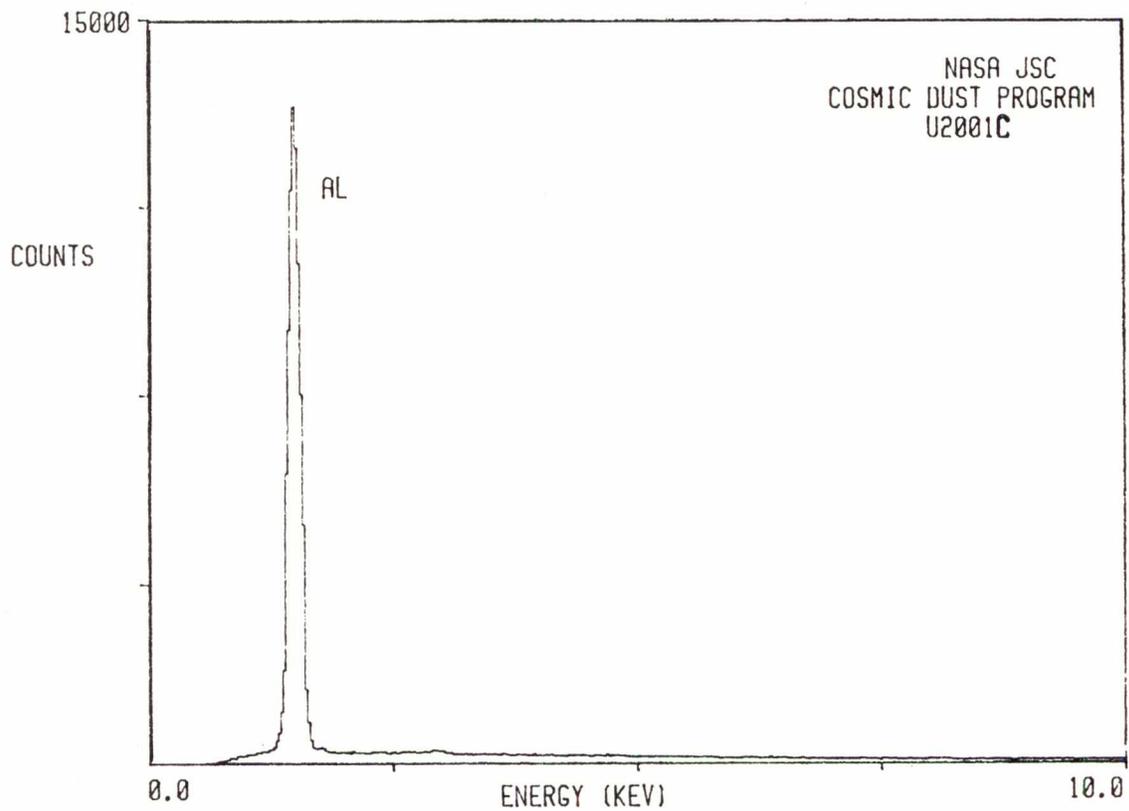
SIZE SHAPE TRANS.
10 S TL

COLOR LUSTER
CL to Pale Yellow V

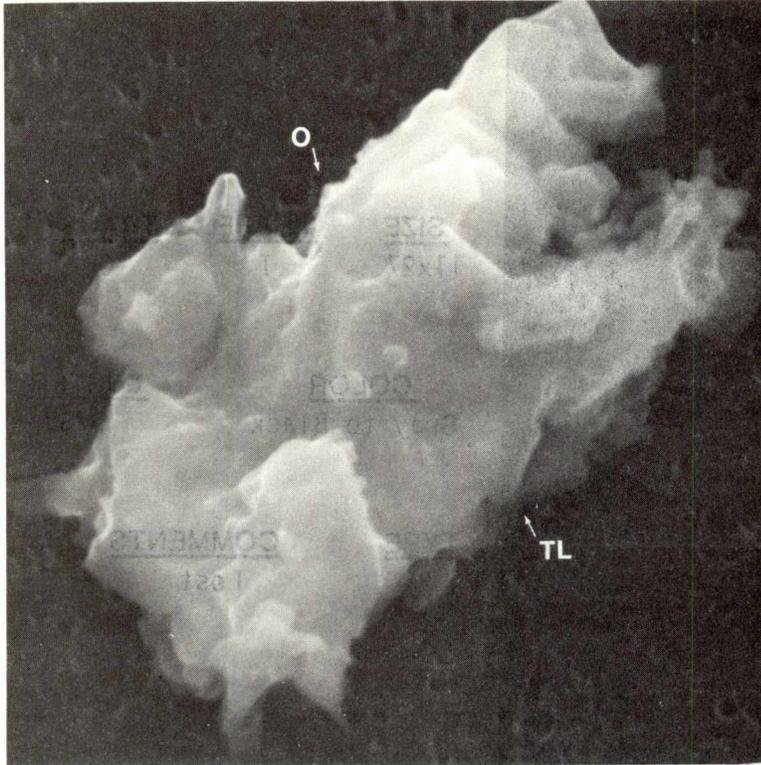
TYPE COMMENTS
AOS

U207C

S-82-35221



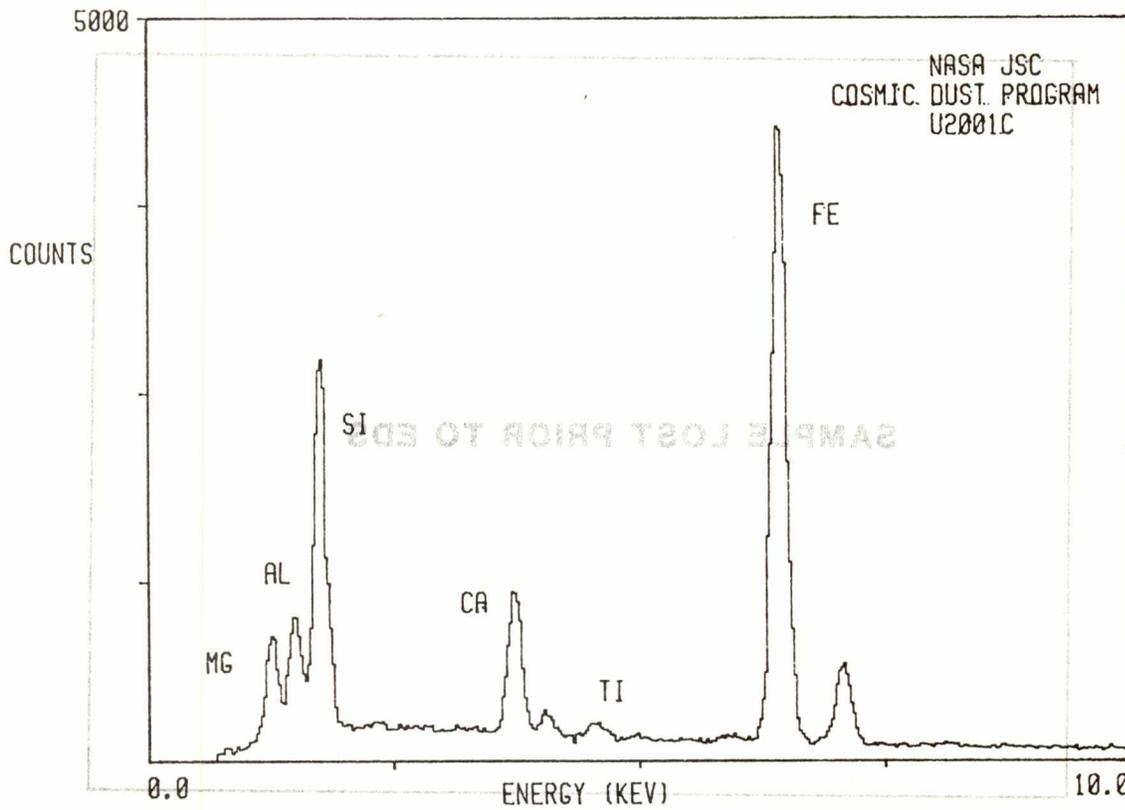
U2001C8



<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
8x14	I	0/TL
<u>COLOR</u>	<u>LUSTER</u>	
Gray to Black	D/SV	
<u>TYPE</u>	<u>COMMENTS</u>	
C?		

U208C

S-82-35222



U2001C9



S-82-35223

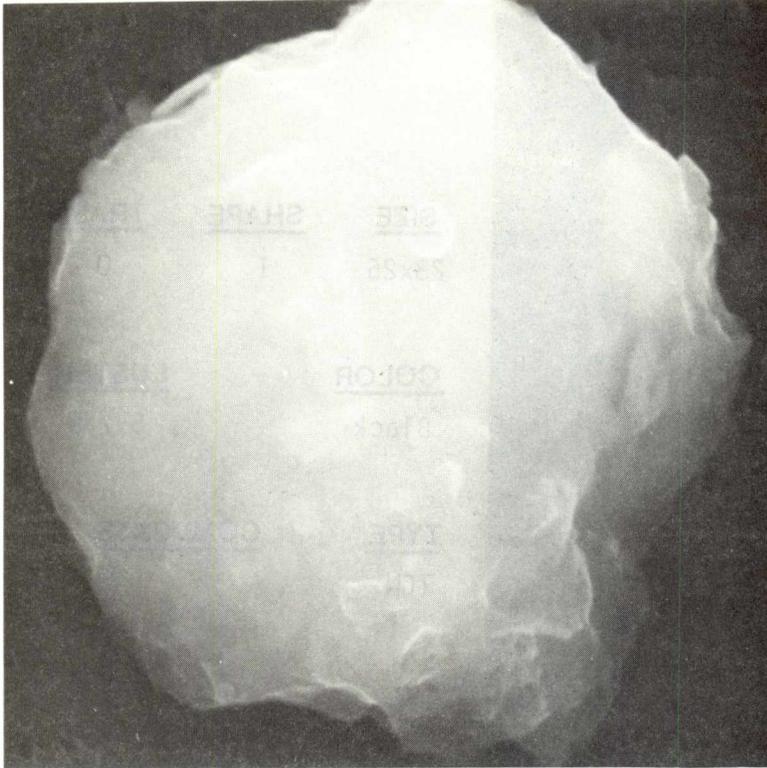
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
11x27	I	0

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

<u>TYPE</u>	<u>COMMENTS</u>
?	Lost

SAMPLE LOST PRIOR TO EDS

U2001C10



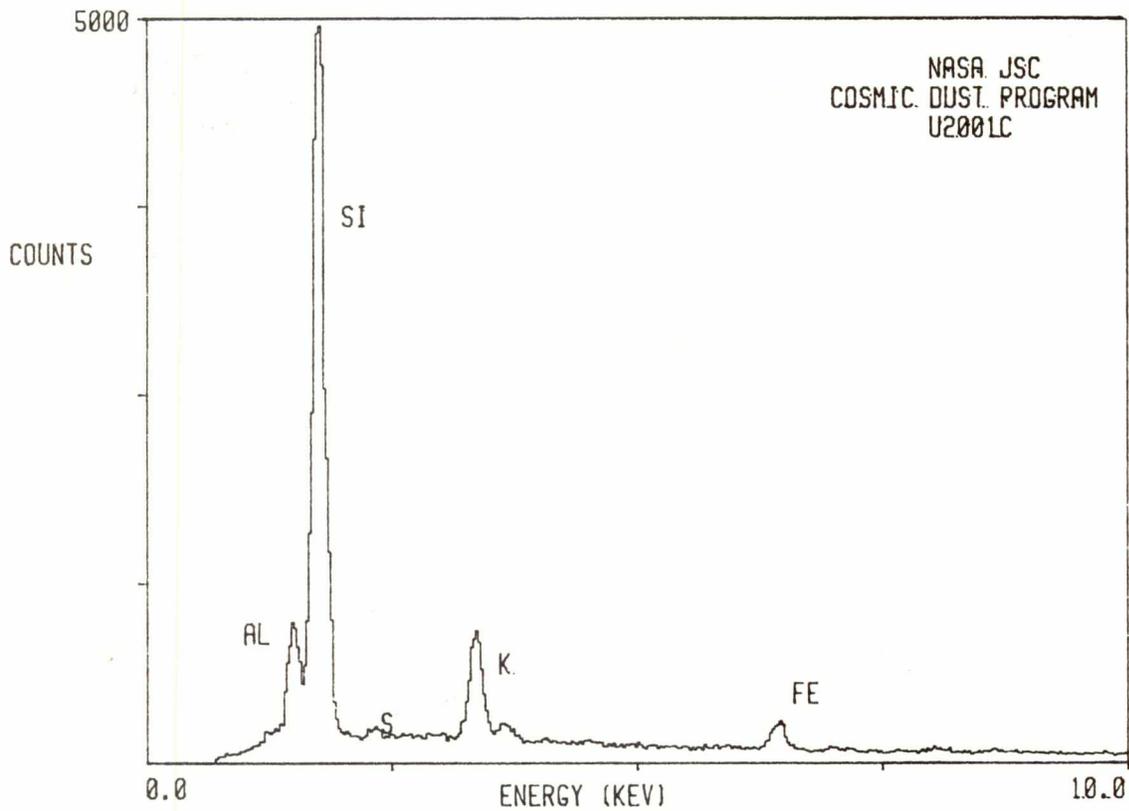
SIZE SHAPE TRANS.
13x14 I TL

COLOR LUSTER
Yellow to Gray SV

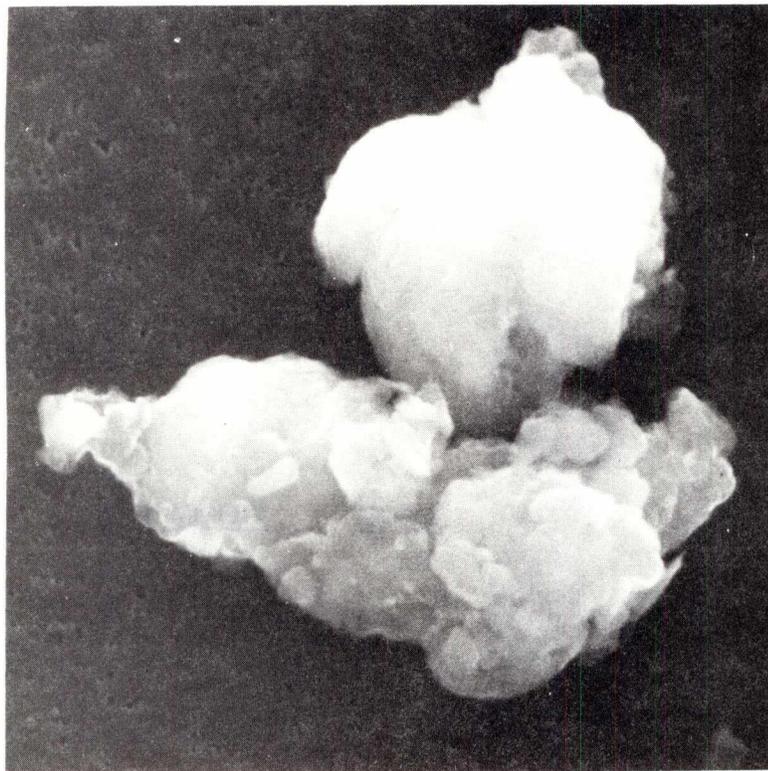
TYPE COMMENTS
TCN

U210C

S-82-35224



U2001C11



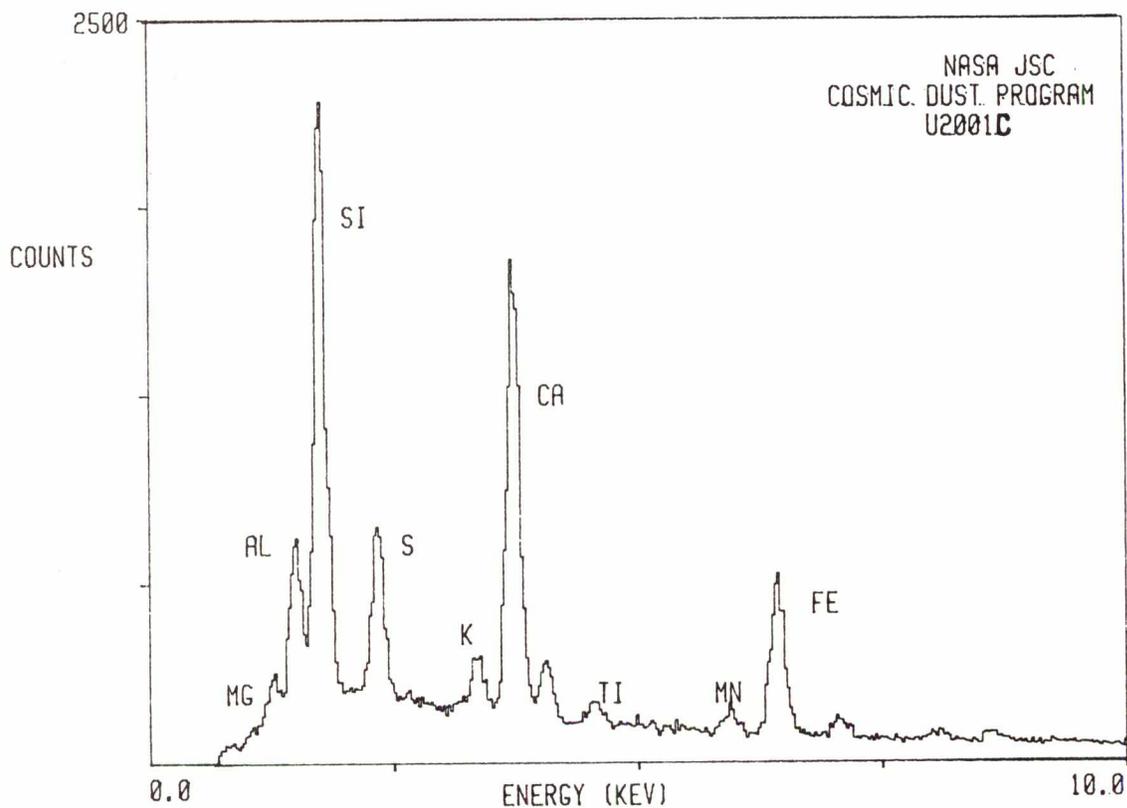
SIZE SHAPE TRANS
23x25 I 0

COLOR LUSTER
Black SV/SM

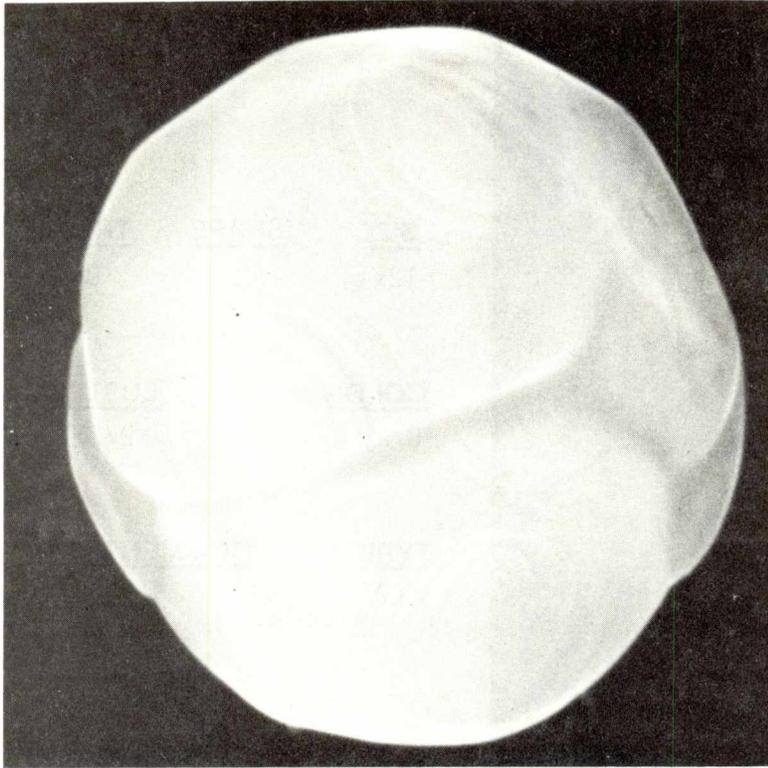
TYPE COMMENTS
TCN

U211C

S-82-35225



U2001C12



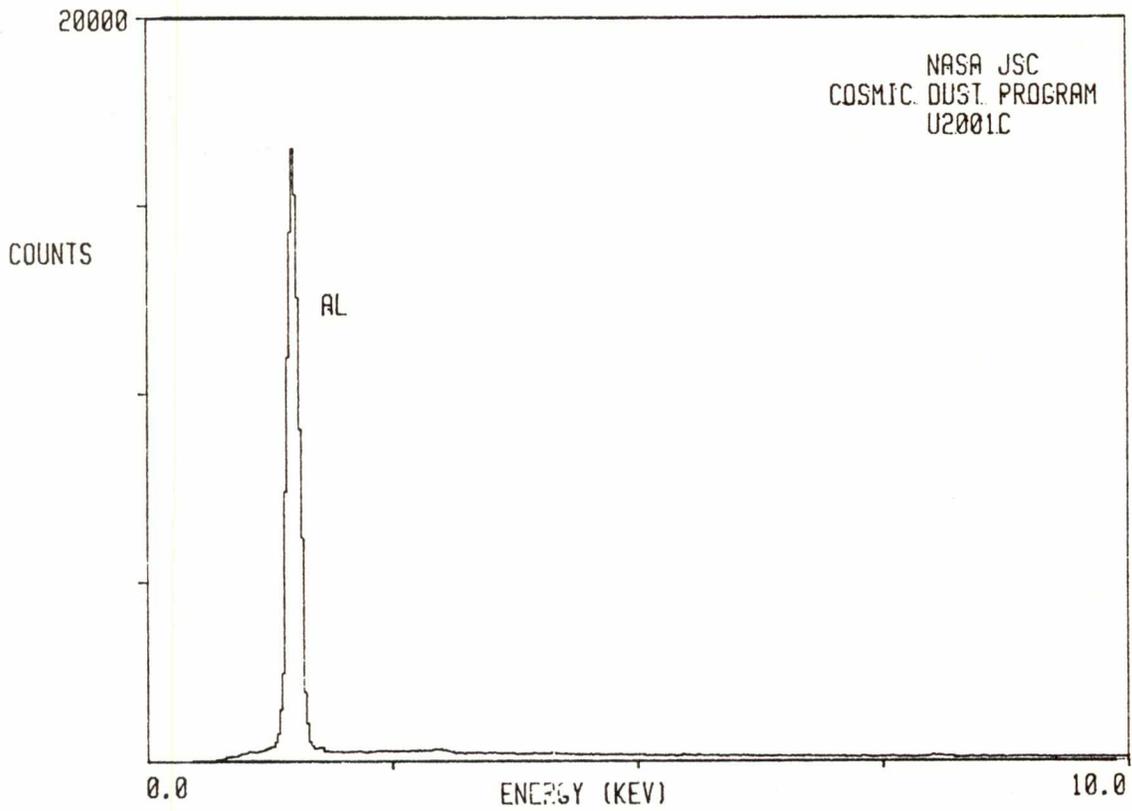
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
12	S	T

<u>COLOR</u>	<u>LUSTER</u>
CL to Pale Yellow	V

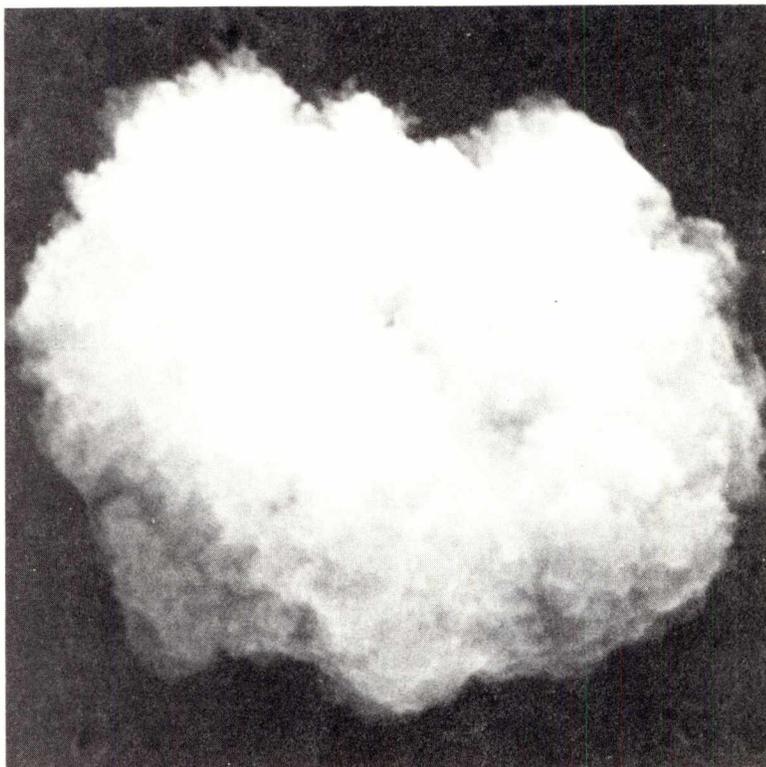
<u>TYPE</u>	<u>COMMENTS</u>
AOS	

S-82-35226

U212C



U2001C13



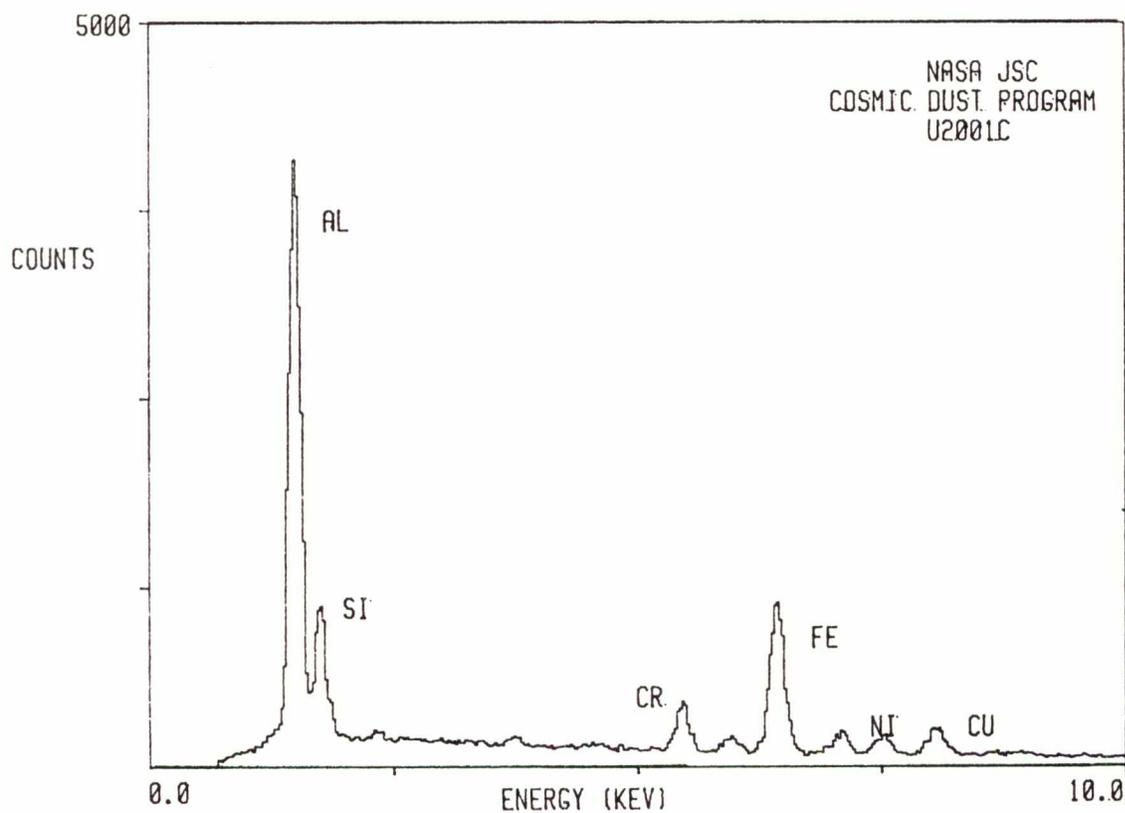
SIZE SHAPE TRANS.
12x14 I 0

COLOR LUSTER
Gray D/SM

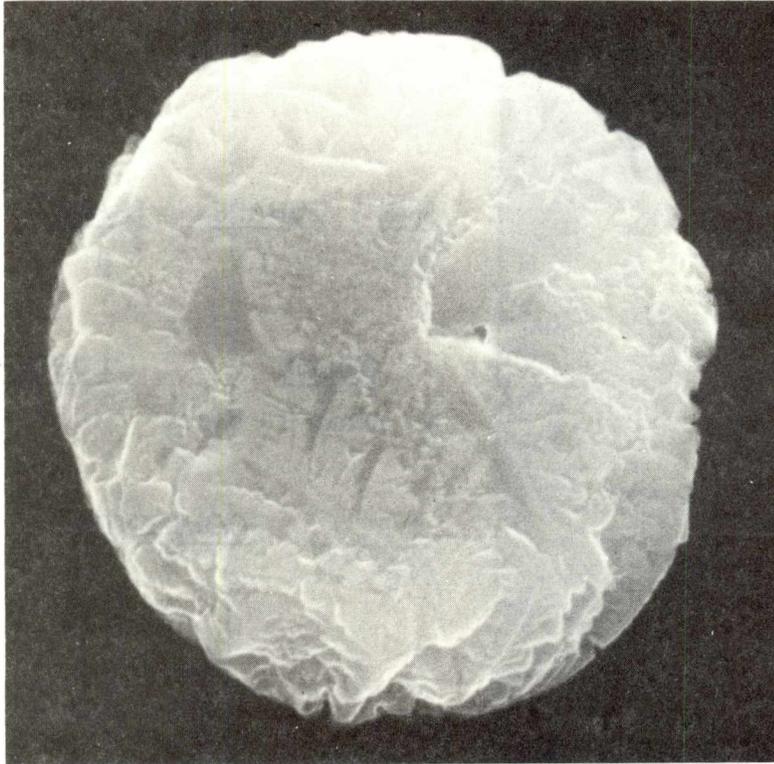
TYPE COMMENTS
TCA?

S-82-35227

U213C



U2001C14



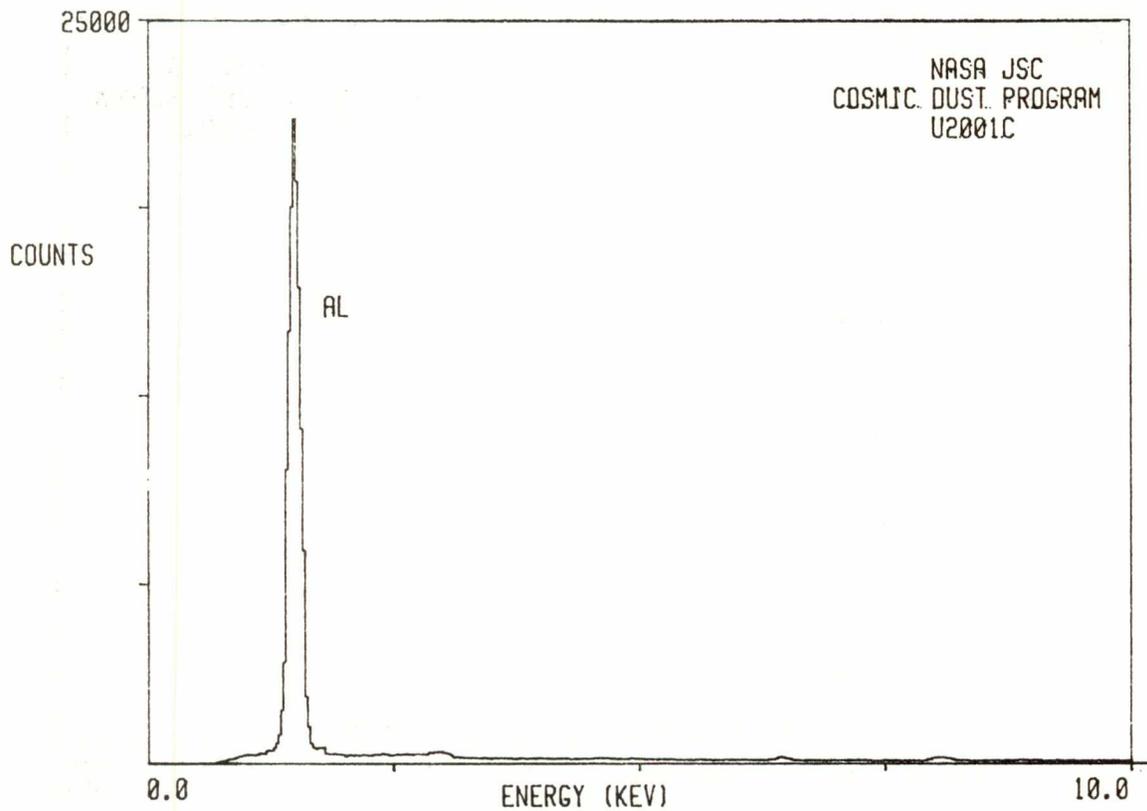
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
15x16	E/I	0

<u>COLOR</u>	<u>LUSTER</u>
Steel Gray	M

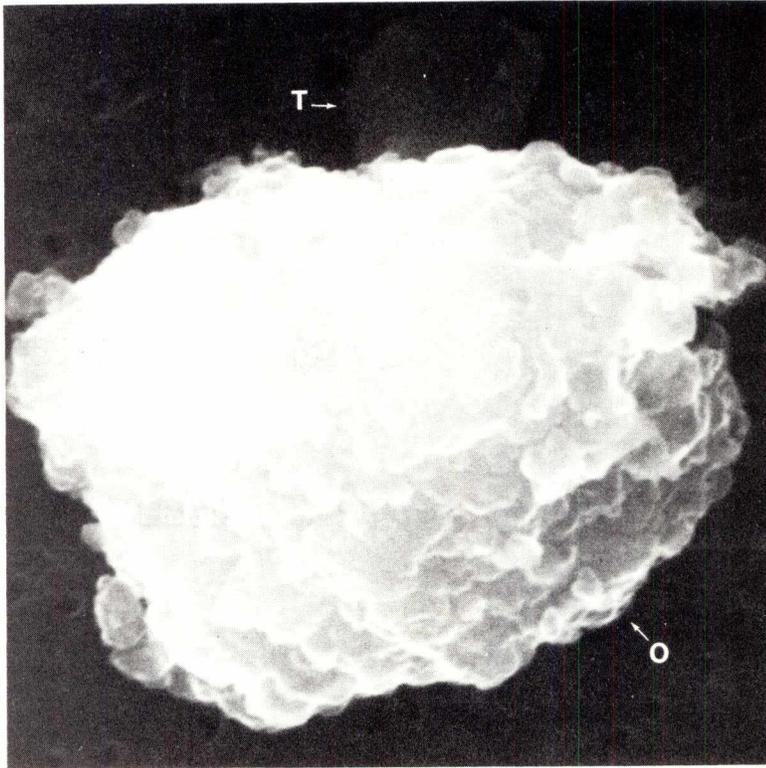
<u>TYPE</u>	<u>COMMENTS</u>
TCA	

S-82-35228

U214C



U2001C15



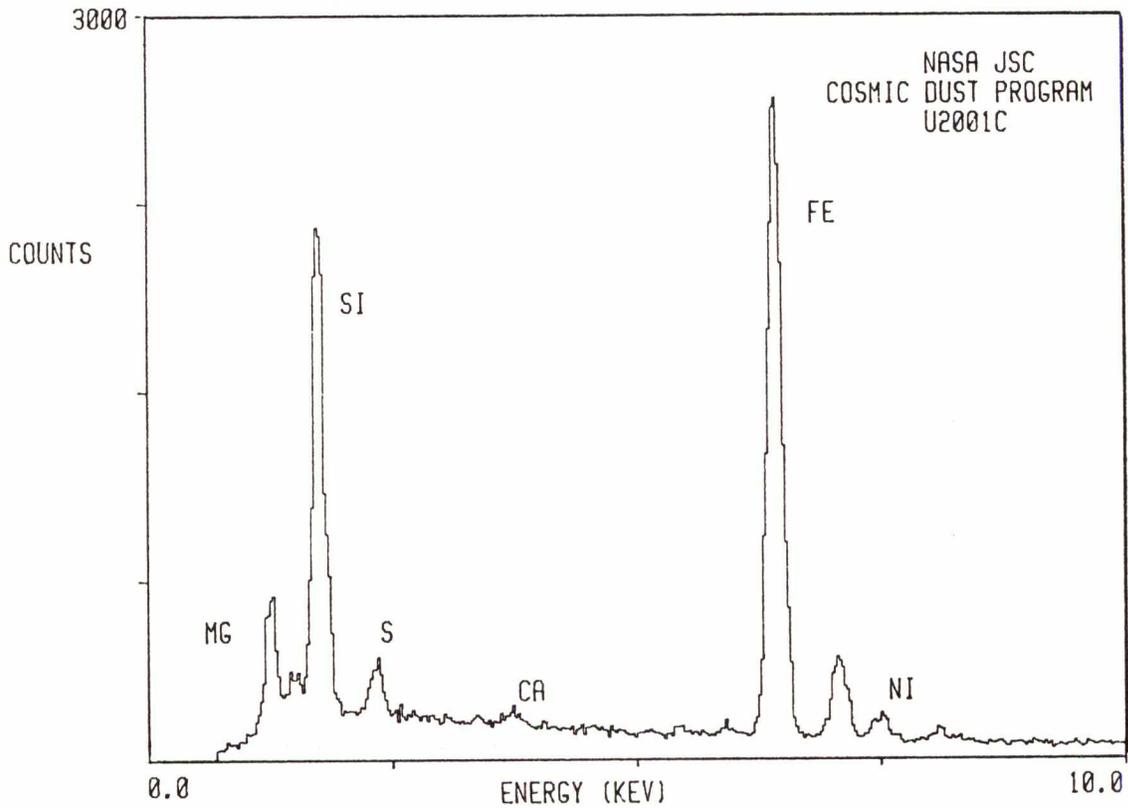
U215C

S-82-35229

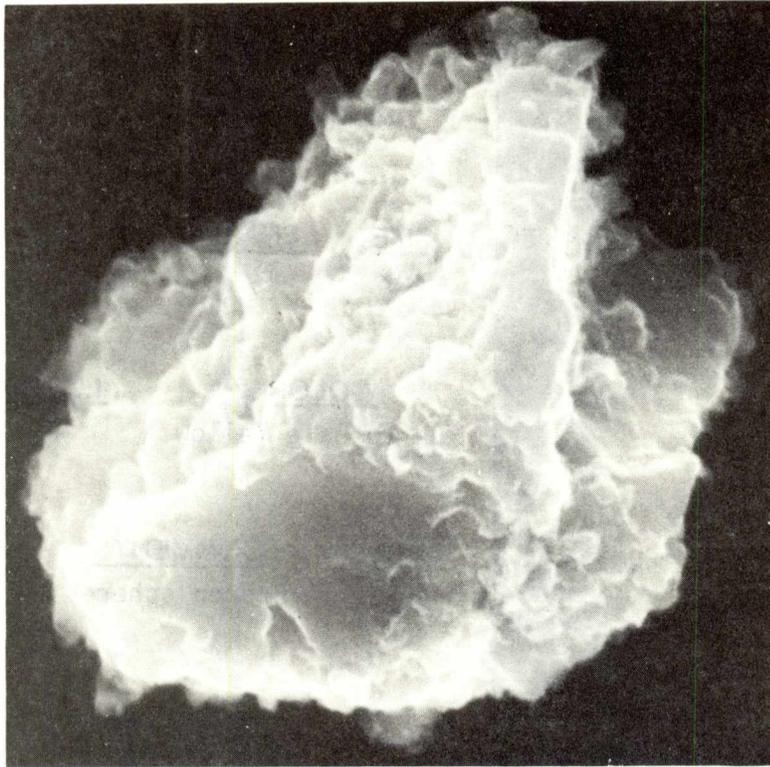
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
7x9	I	0

<u>COLOR</u>	<u>LUSTER</u>
Dk. Brown to Black	SV

<u>TYPE</u>	<u>COMMENTS</u>
C	



U2001C16



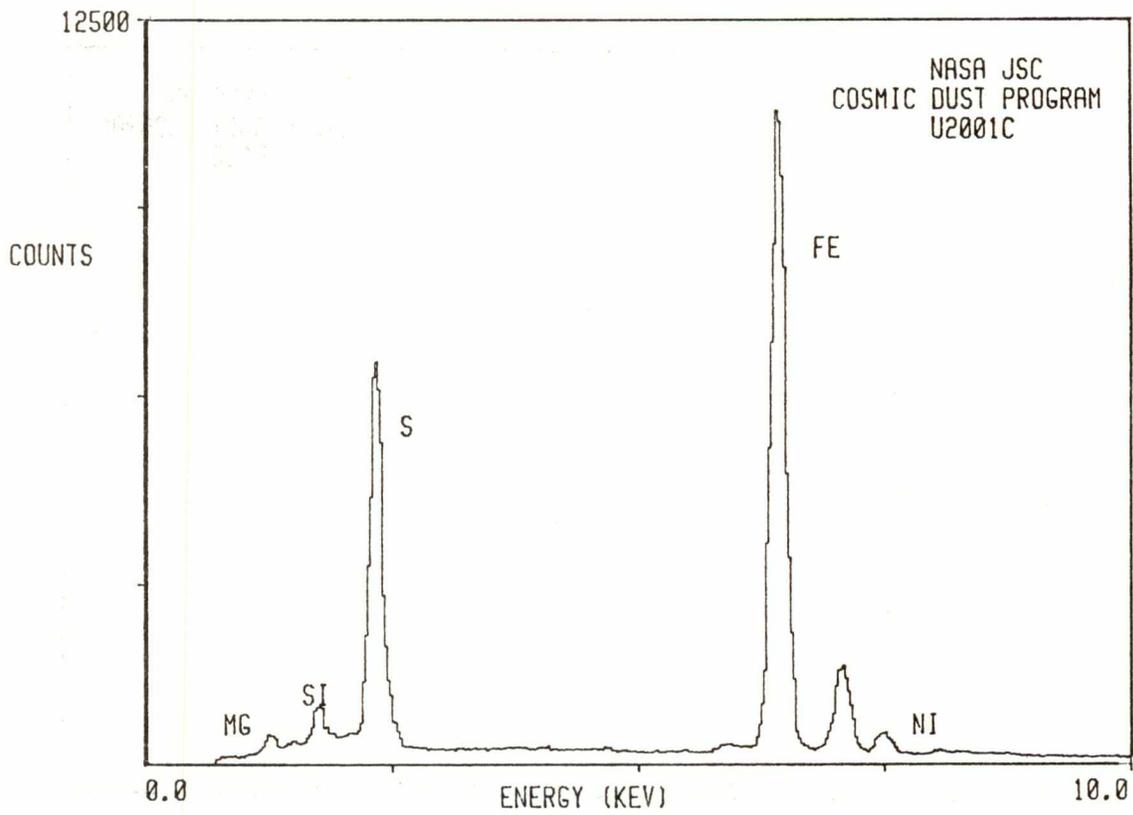
SIZE SHAPE TRANS.
13x18 I 0

COLOR LUSTER
Gray to Black SV/SM

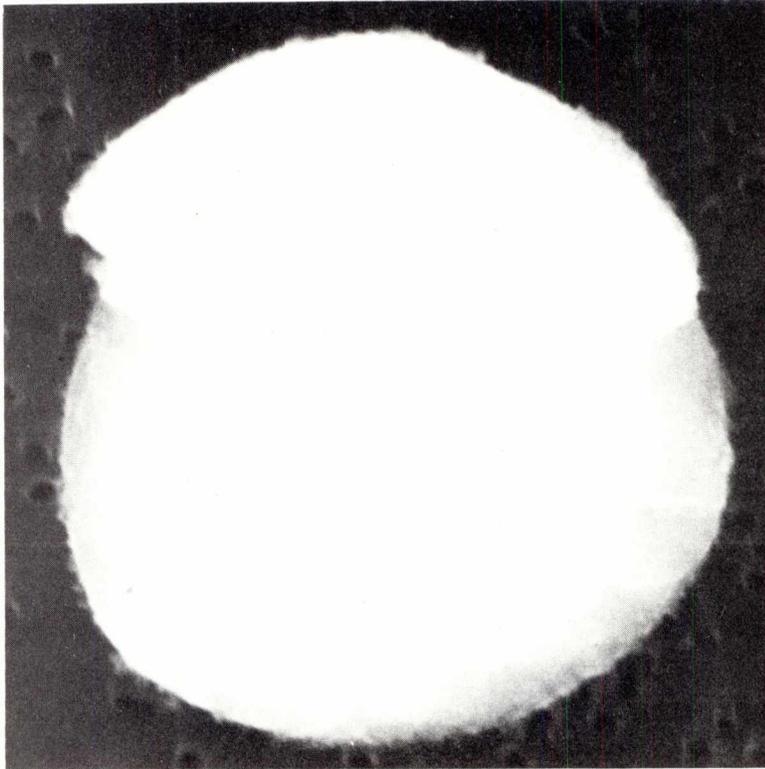
TYPE COMMENTS
C

U216C

S-82-35230



U2001C17



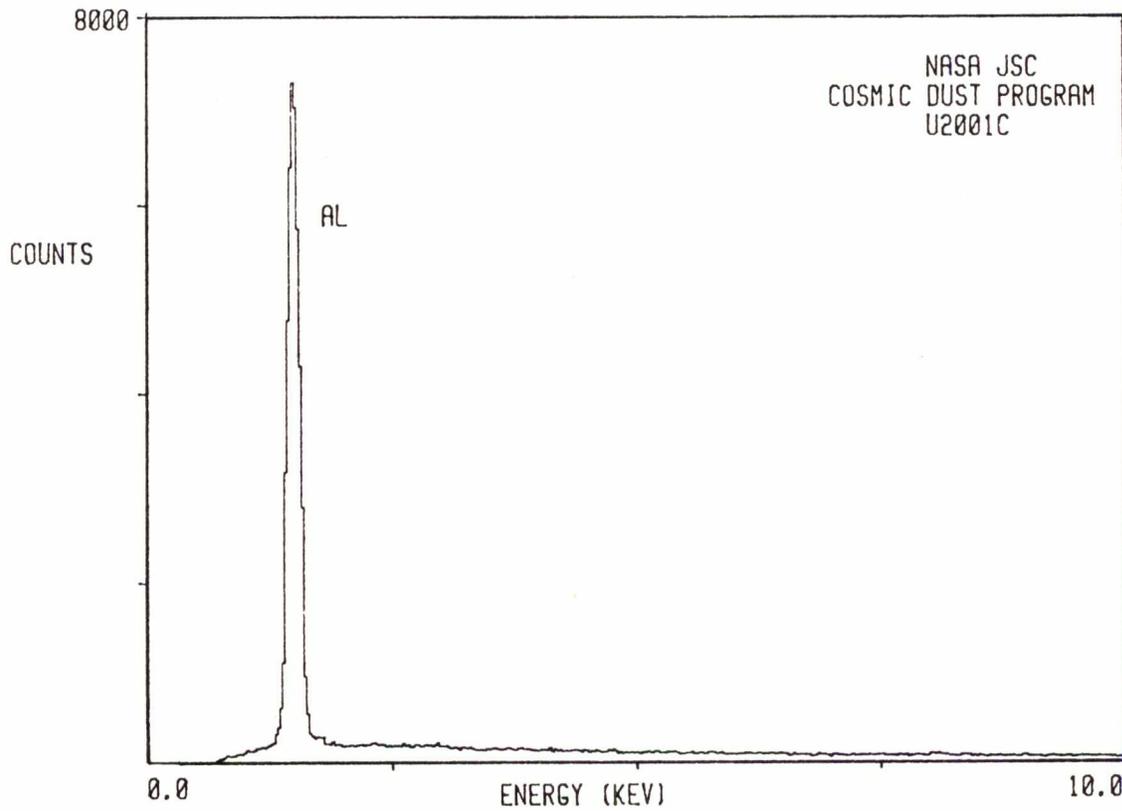
SIZE SHAPE TRANS.
8x8 E/S T/TL

COLOR LUSTER
CL to Pale Yellow V

TYPE COMMENTS
AOS Broken sphere

U217C

S-82-35231



MOUNT U2001D

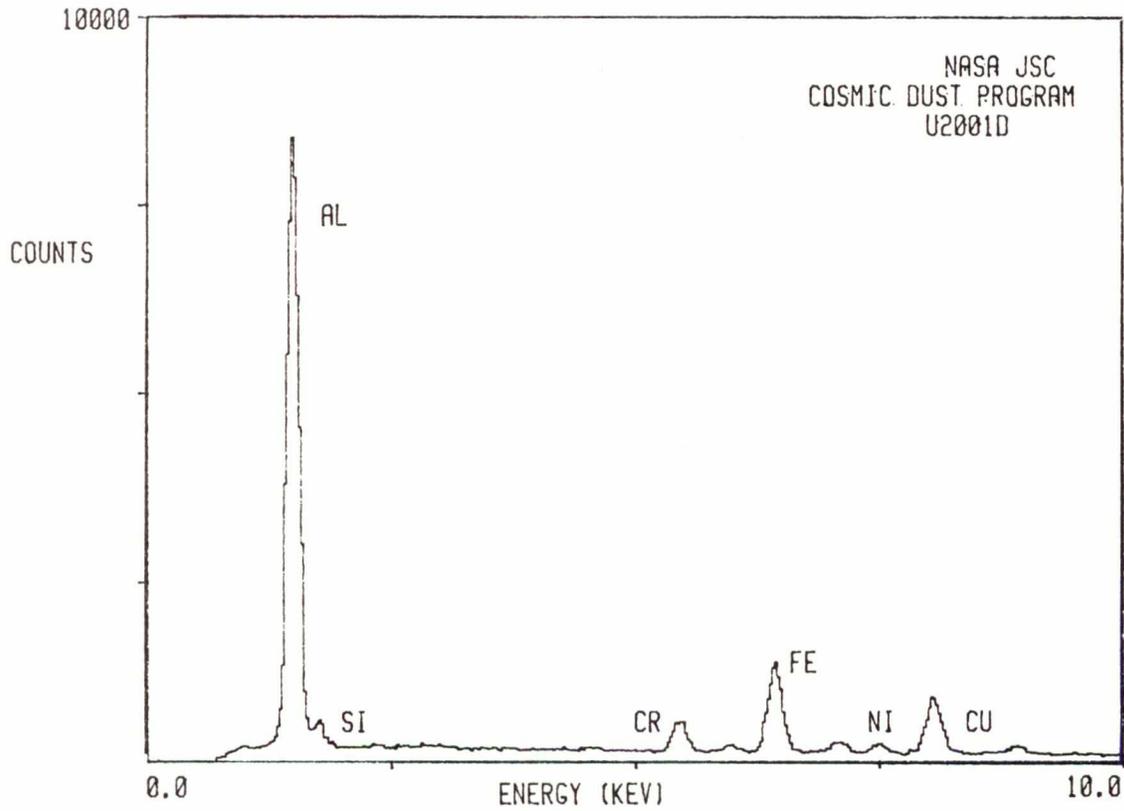
U2001D1



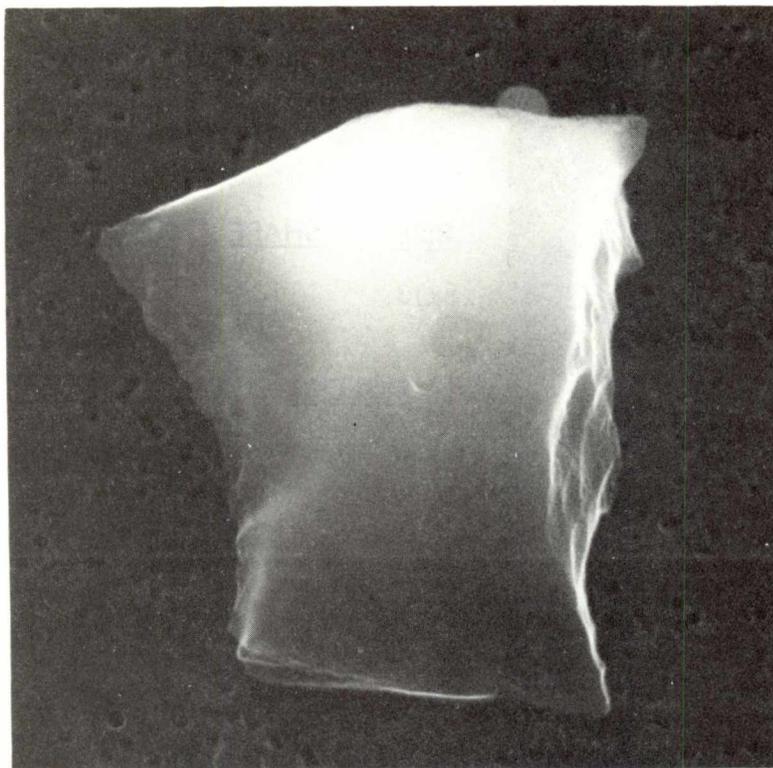
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
14x15	E/I	0
<u>COLOR</u>	<u>LUSTER</u>	
Gray	SM	
<u>TYPE</u>	<u>COMMENTS</u>	
TCA?		

U201D

S-82-35200



U2001D2



SIZE SHAPE TRANS.

11x12 I 0

COLOR LUSTER

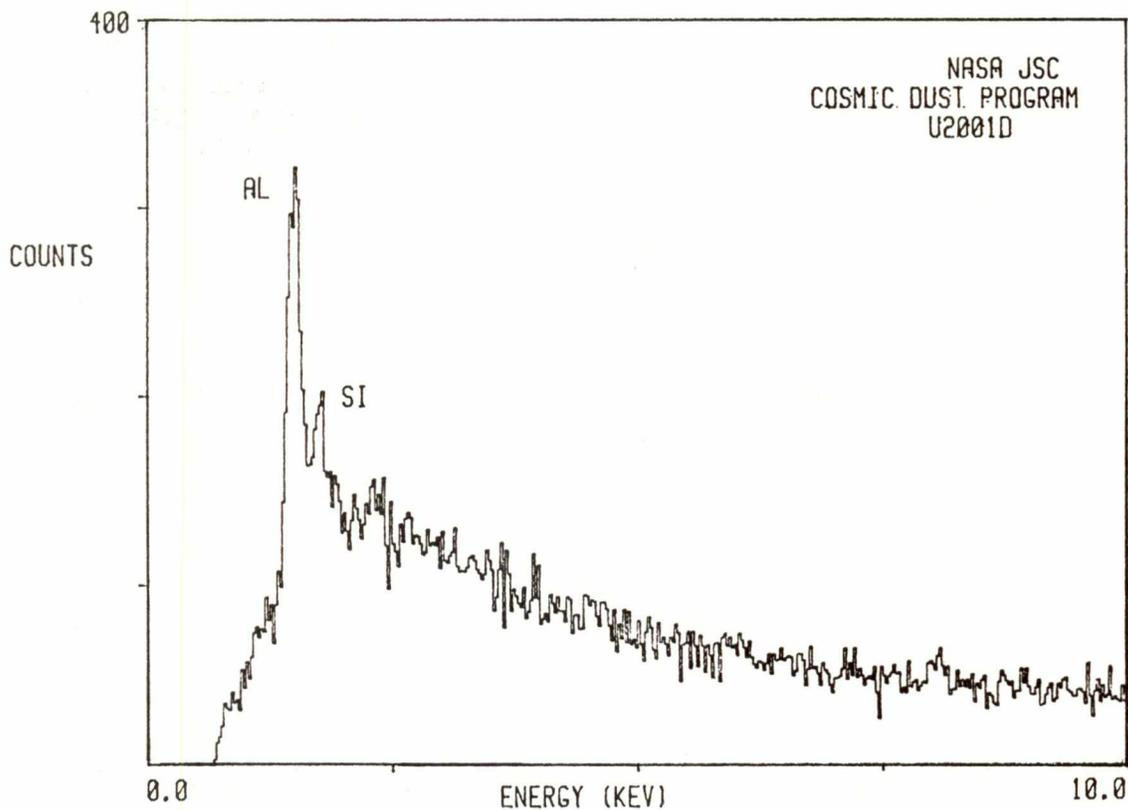
Dk. Brown to Black D/SV

TYPE COMMENTS

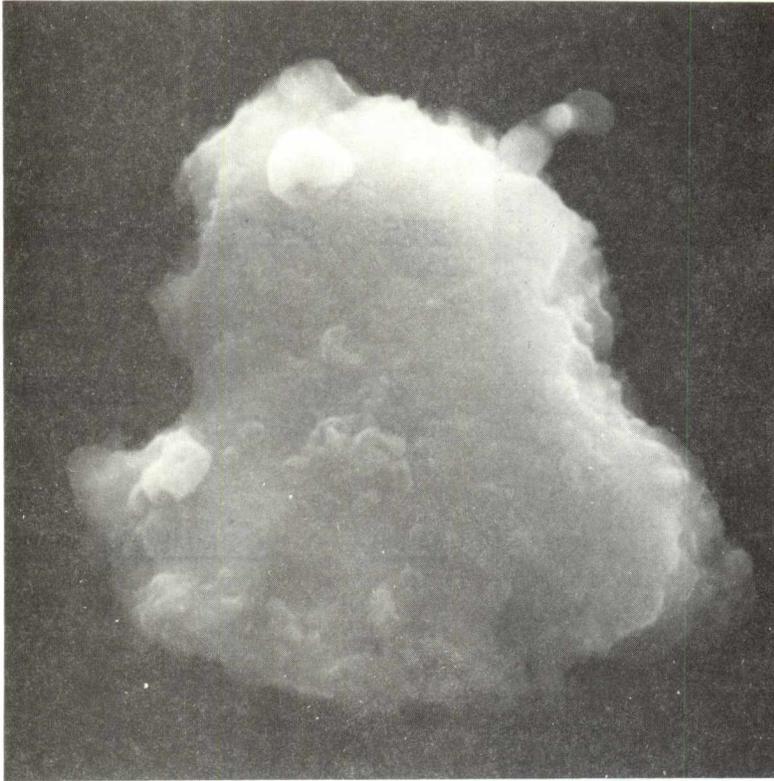
TCA?

S-82-35201

U202D



U2001D4



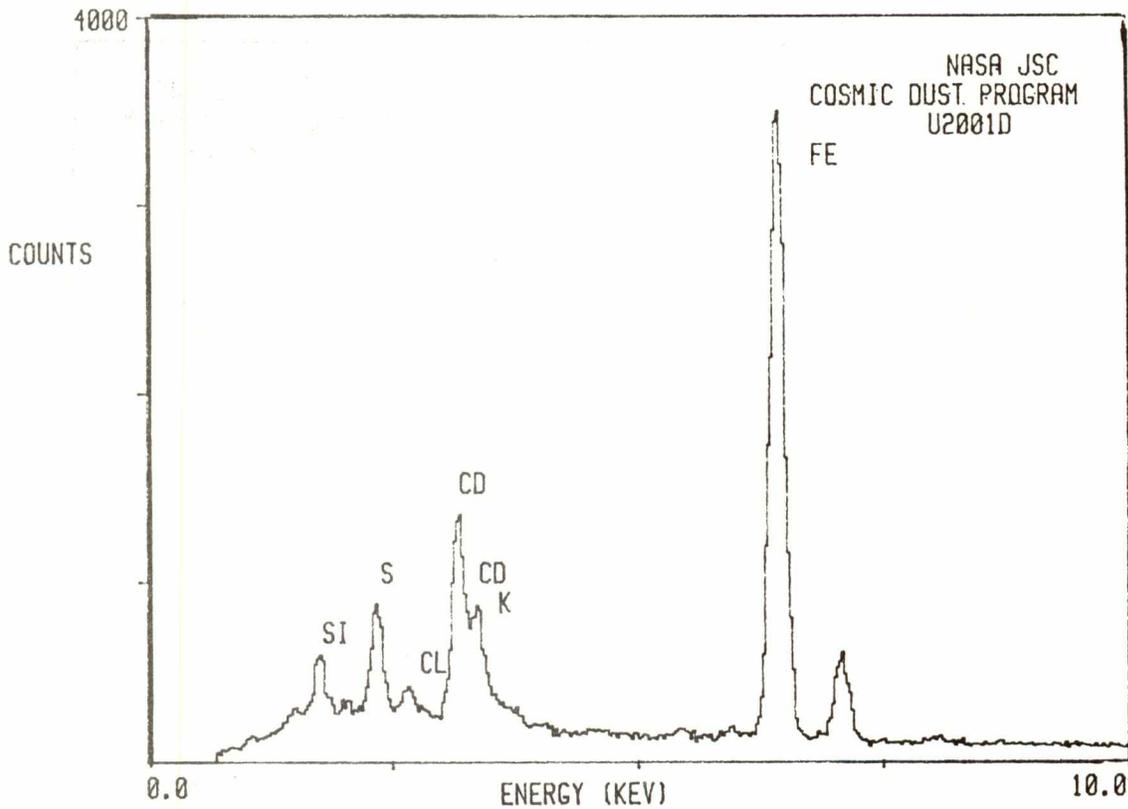
SIZE SHAPE TRANS.
14x17 I 0/TL

COLOR LUSTER
Golden Brown SM

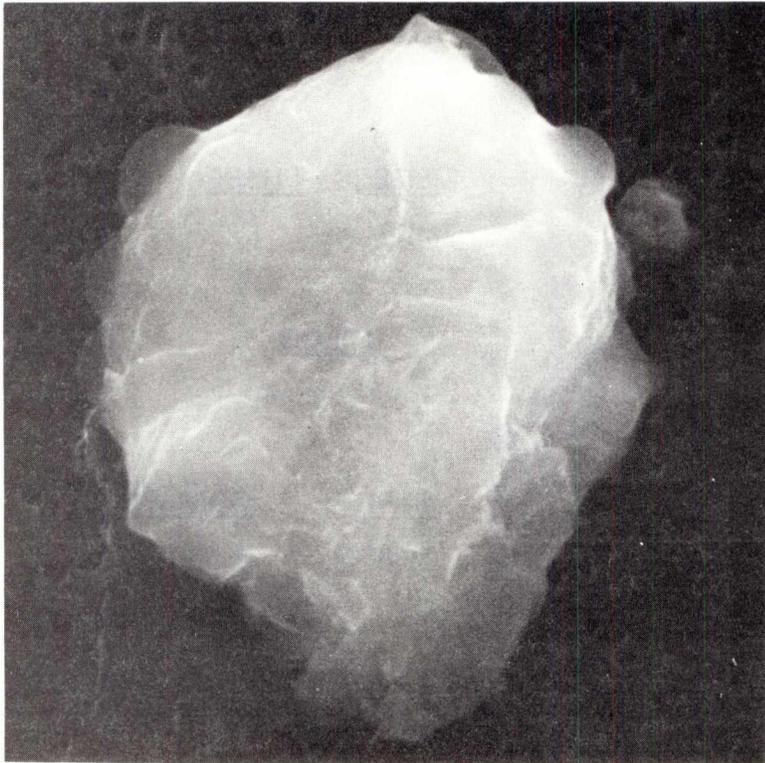
TYPE COMMENTS
TCA?

U204D

S-82-35203



U2001D5



SIZE
8x10

SHAPE
I

TRANS.
0/TL

COLOR
Deep Orange-Red

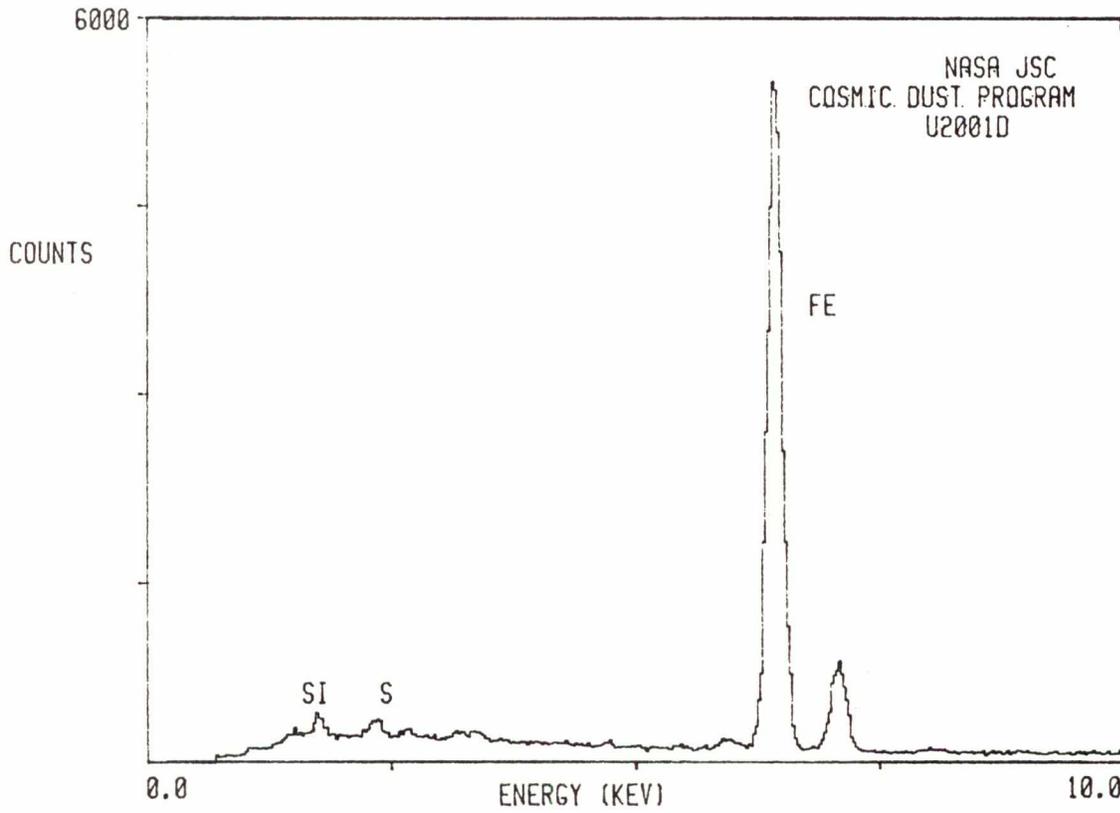
LUSTER
SV

TYPE
?

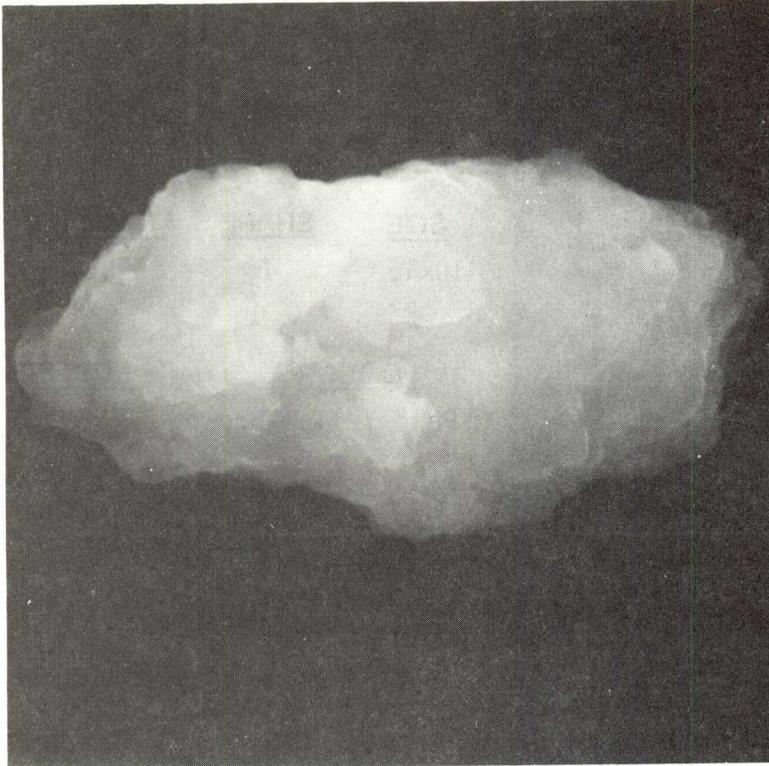
COMMENTS

U2050

S-82-35204



U2001D6



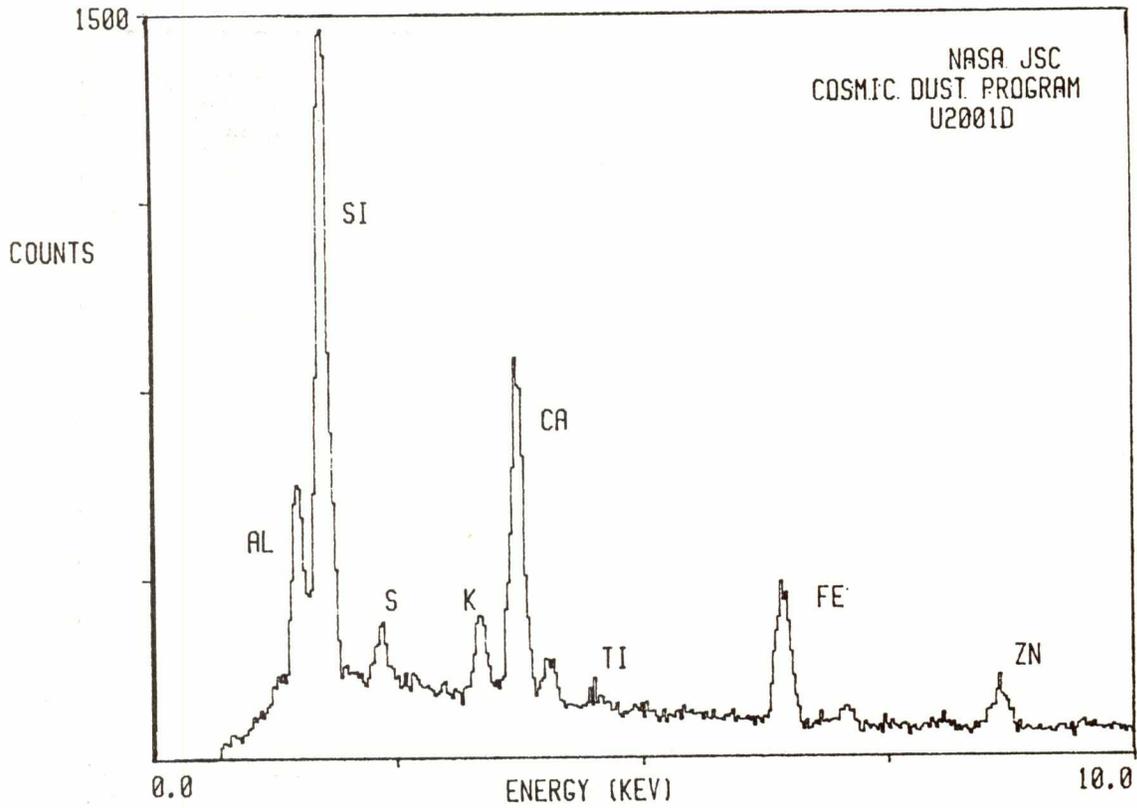
SIZE SHAPE TRANS.
12x23 I 0/TL

COLOR LUSTER
Gray-Brown SV

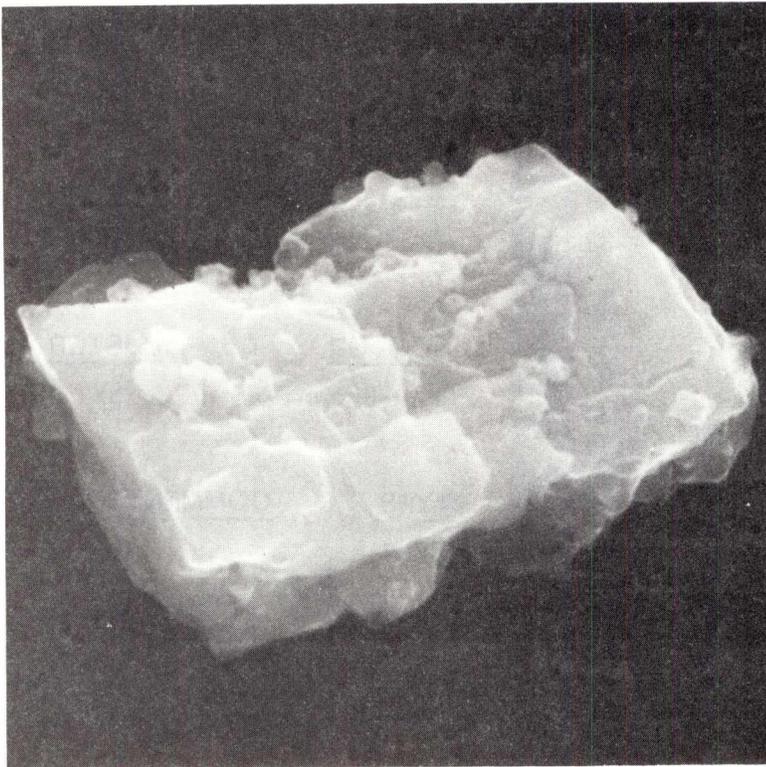
TYPE COMMENTS
TCN?

U206D

S-82-35205



U2001D7



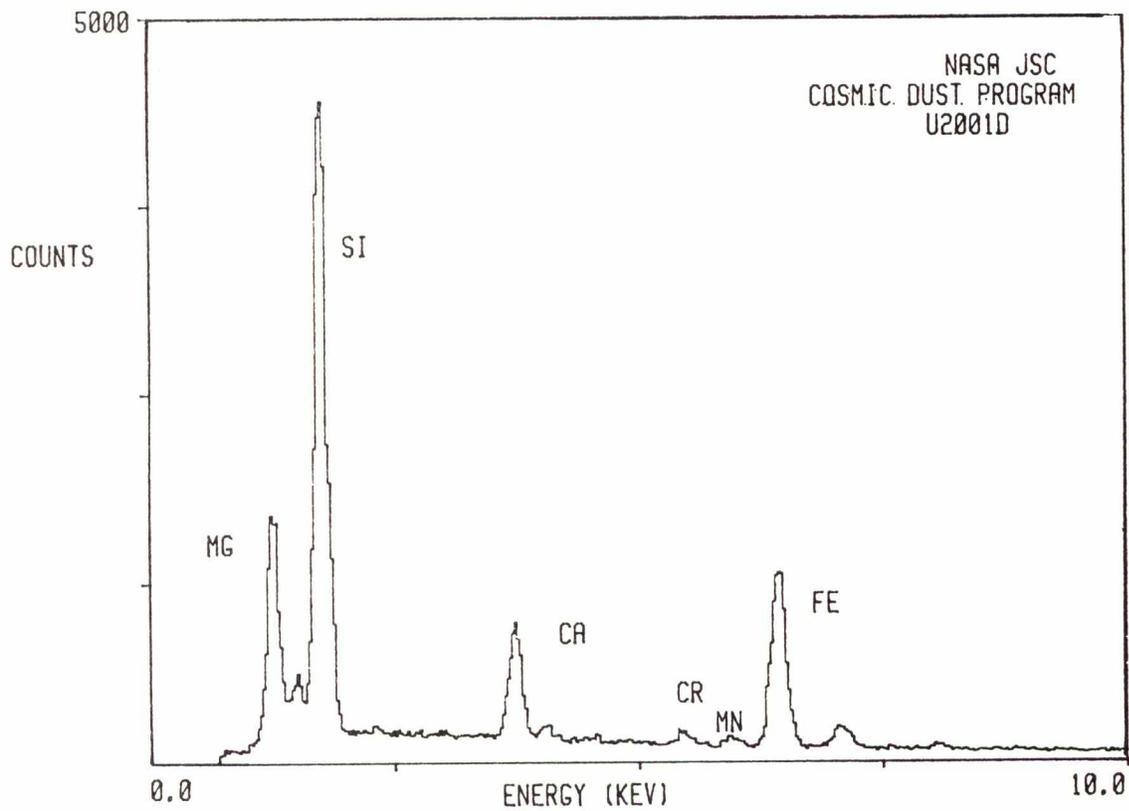
SIZE SHAPE TRANS.
10x15 I TL

COLOR LUSTER
Pale Yellow-Brown SV

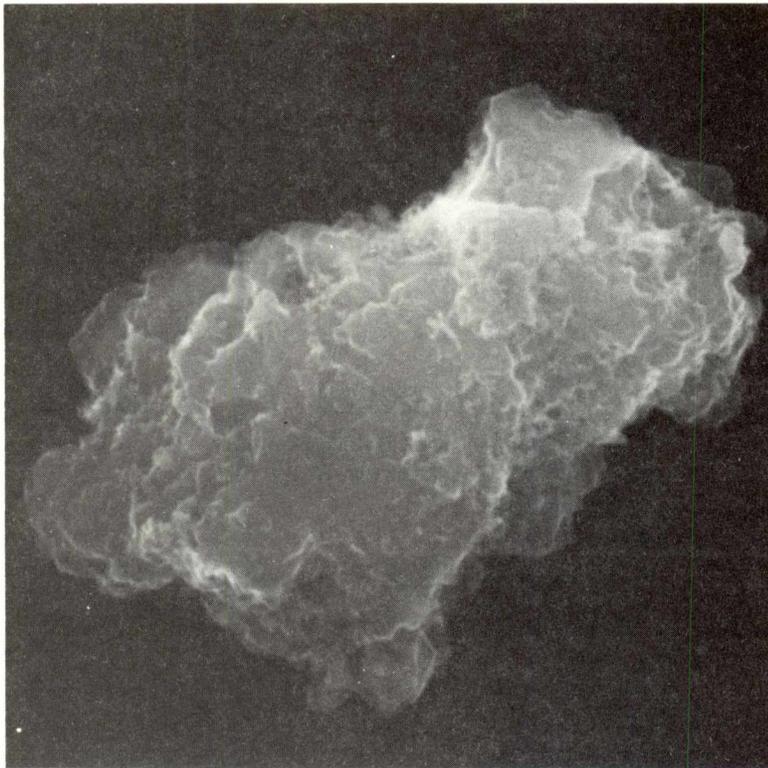
TYPE COMMENTS
C?

S-82-35206

U207D



U2001D8



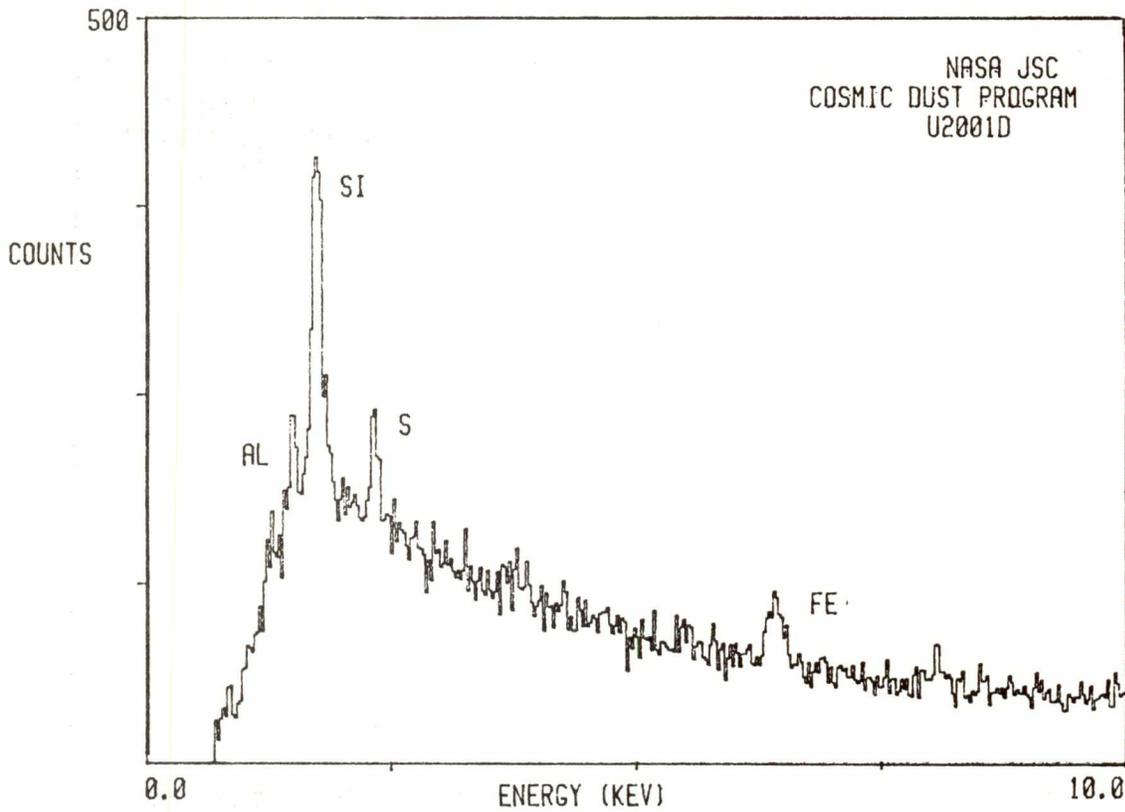
SIZE SHAPE TRANS.
12x18 I 0

COLOR LUSTER
Dk. Brown to Black SV/SM

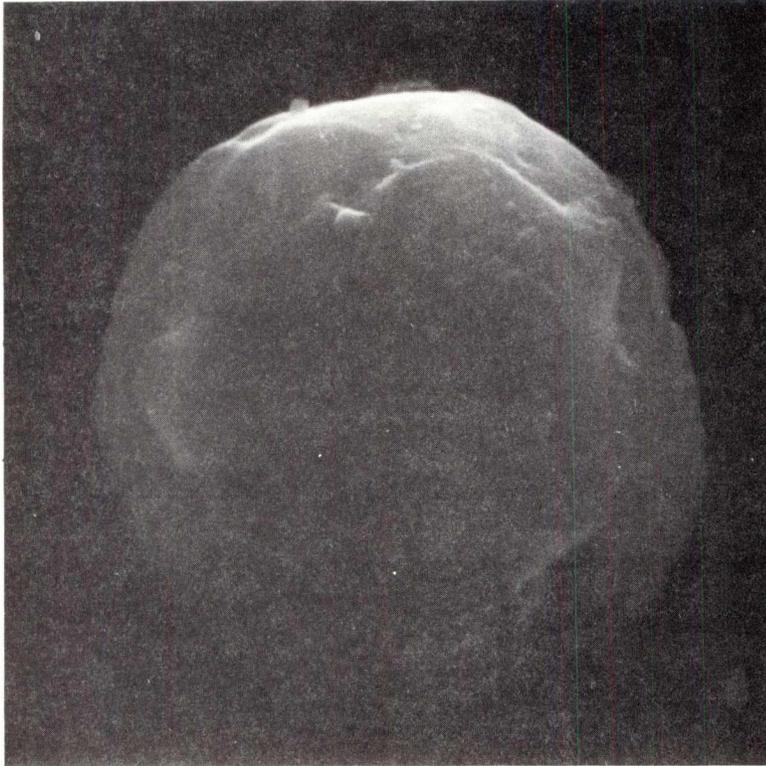
TYPE COMMENTS
?

U208D

S-82-35207



U2001D9



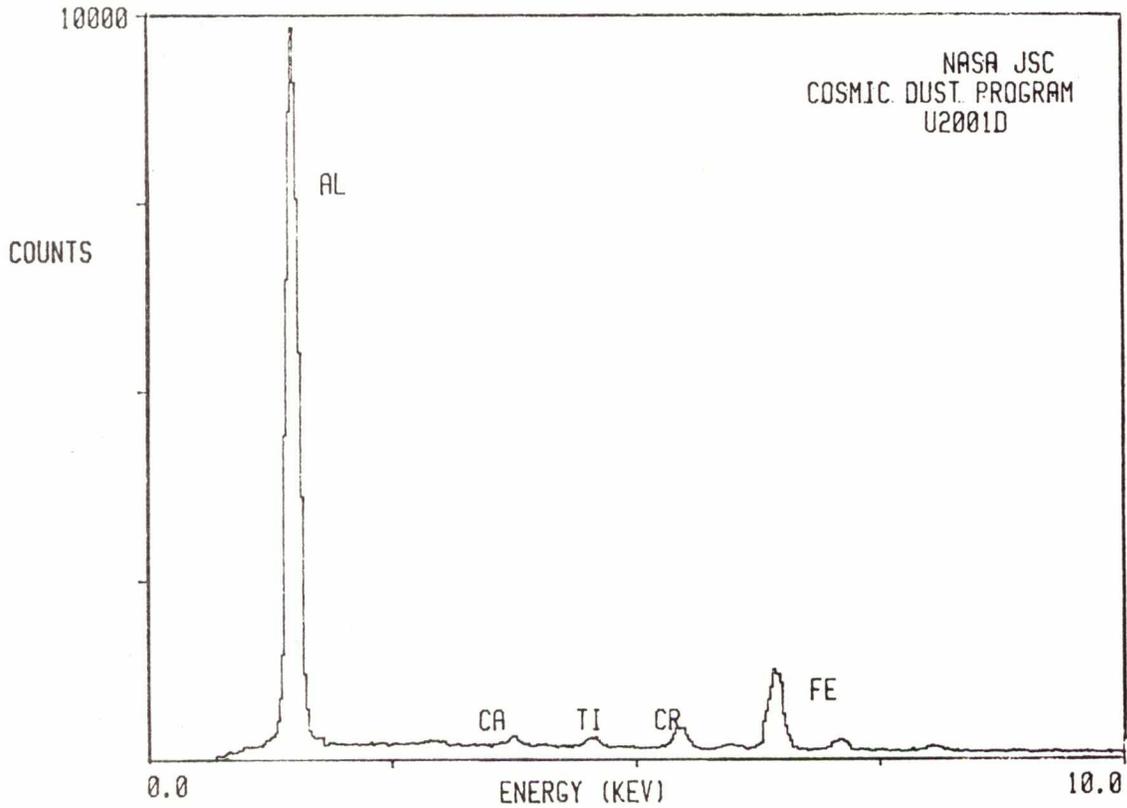
SIZE SHAPE TRANS.
12 S T

COLOR LUSTER
CL to Pale V
Yellow-Gray

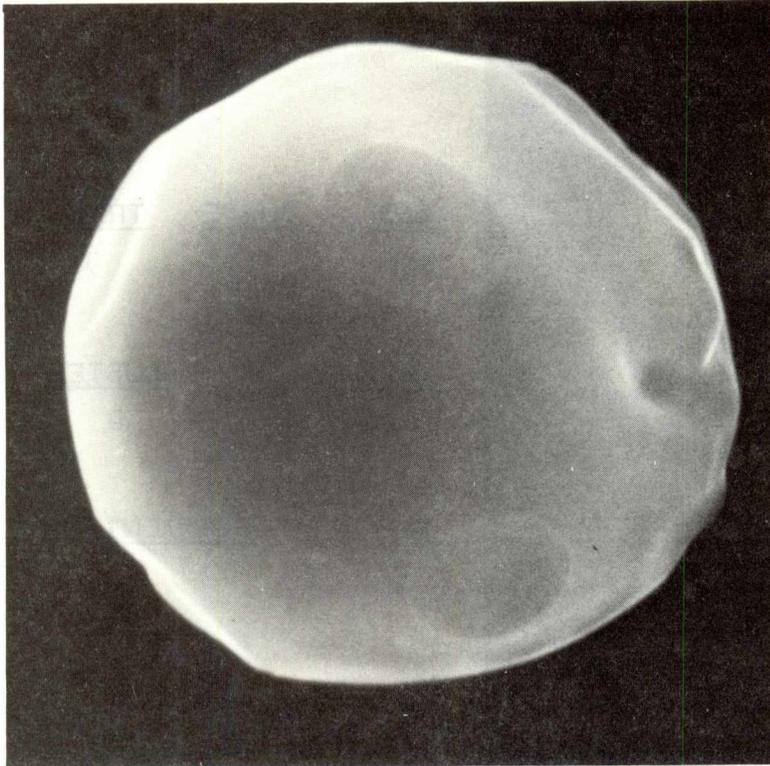
TYPE COMMENTS
?

S-82-35208

U2090



U2001D10



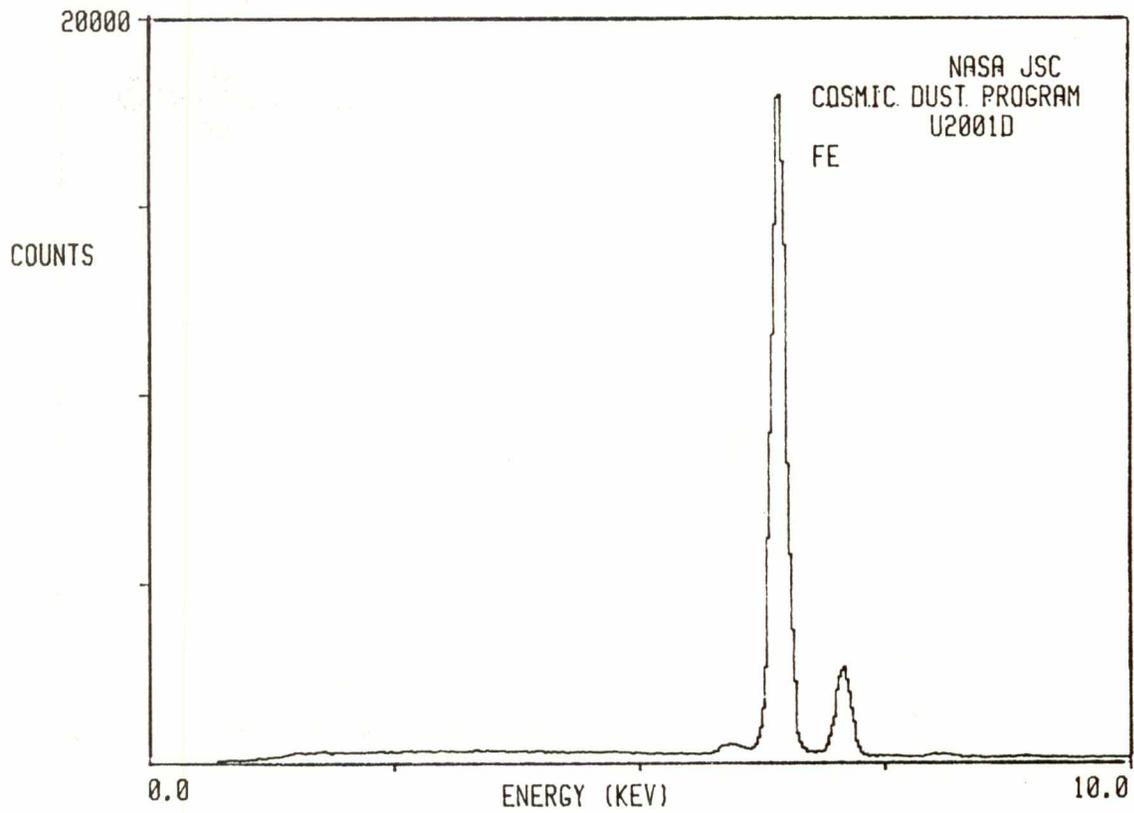
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
9	S	0

<u>COLOR</u>	<u>LUSTER</u>
Black	M

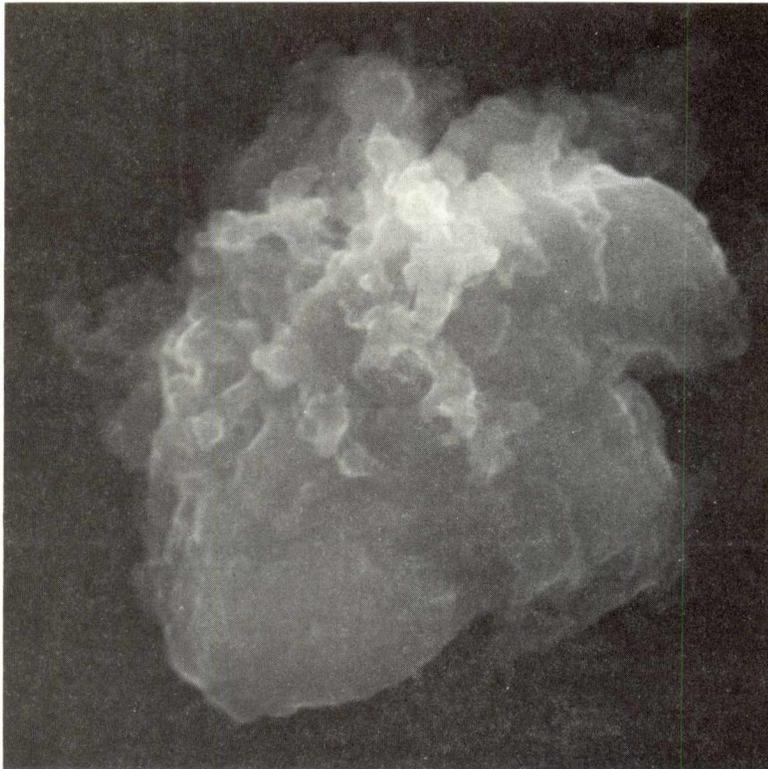
<u>TYPE</u>	<u>COMMENTS</u>
C?	

U2100

S-82-35209



U2001D12



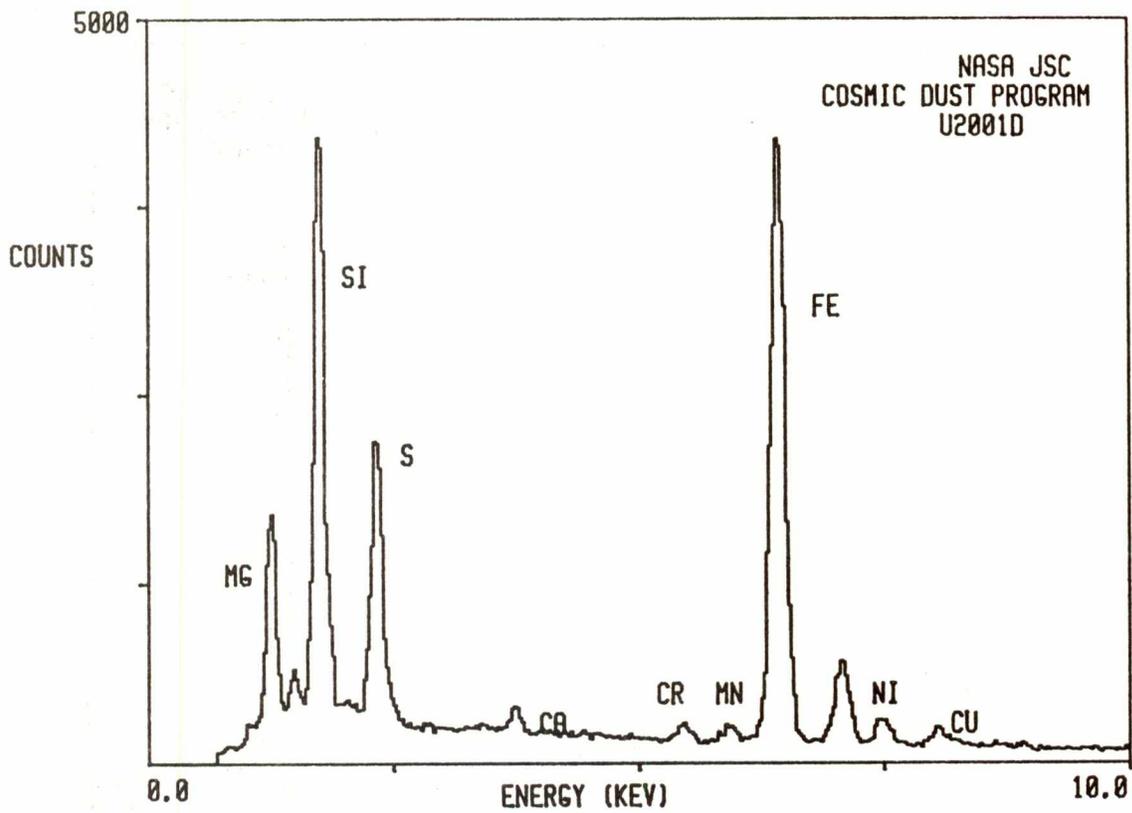
SIZE SHAPE TRANS.
8x12 I 0

COLOR LUSTER
Dk. Brown D/SV
to Black

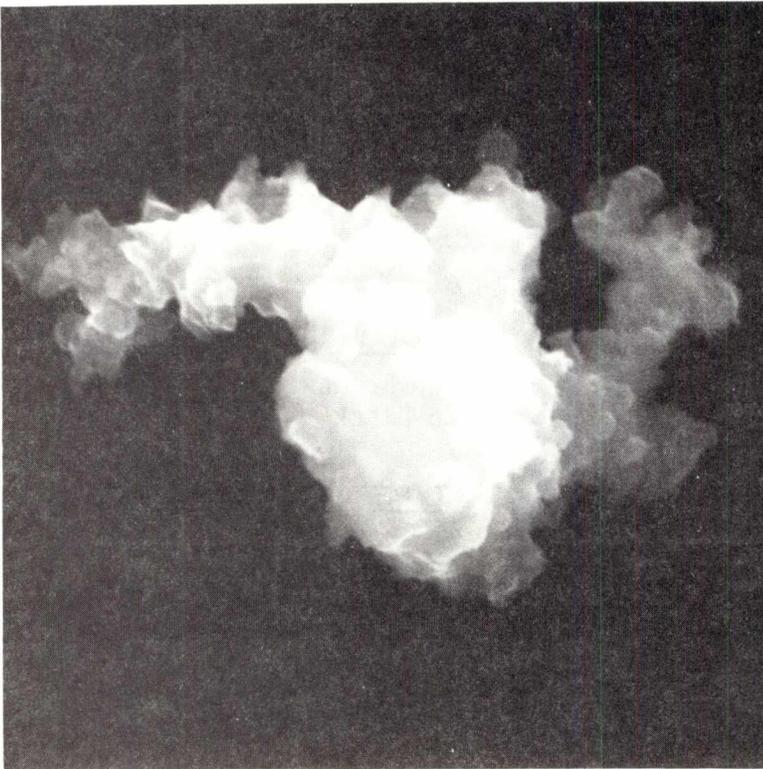
TYPE COMMENTS
C?

U212D

S-82-35211



U2001D13



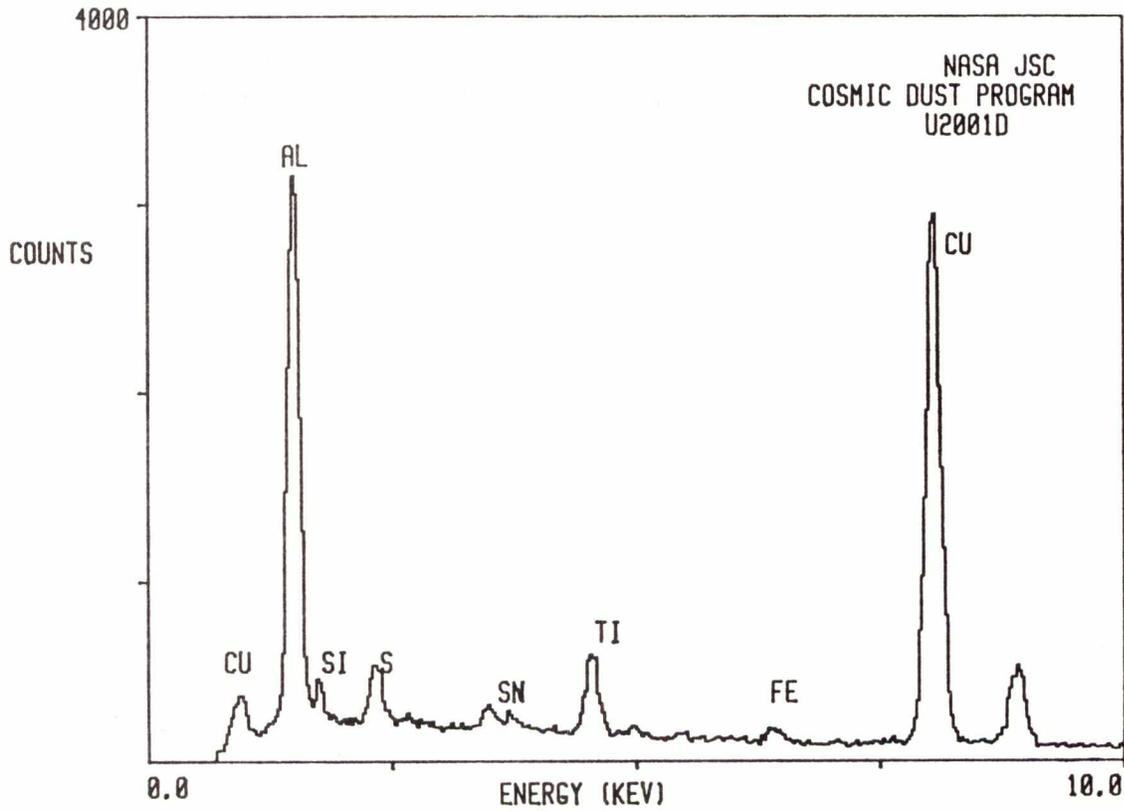
SIZE SHAPE TRANS.
11x16 I 0

COLOR LUSTER
Dk. Brown to Black SV/SM

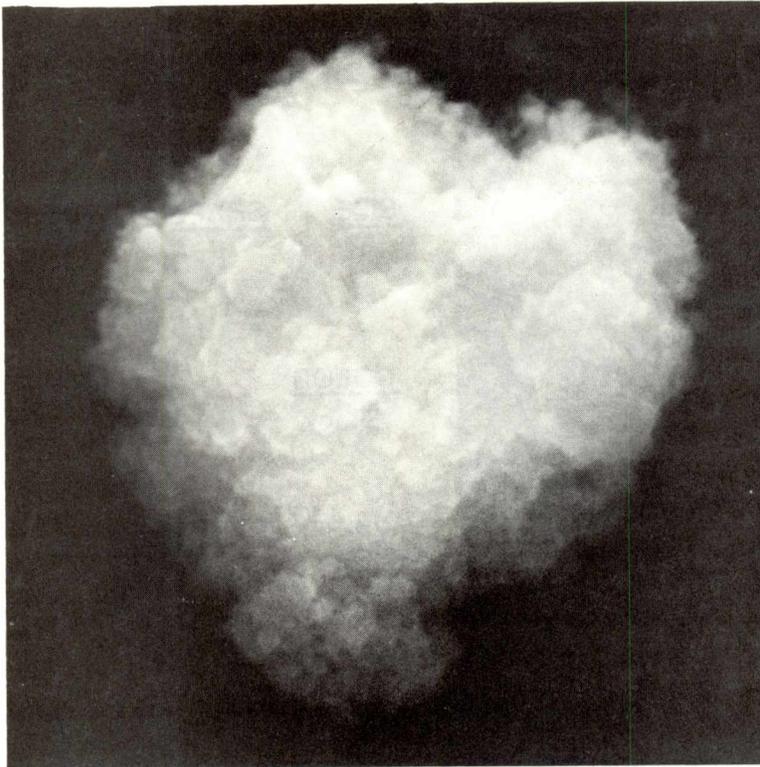
TYPE COMMENTS
TCA?

U213D

S-82-35212



U2001D14



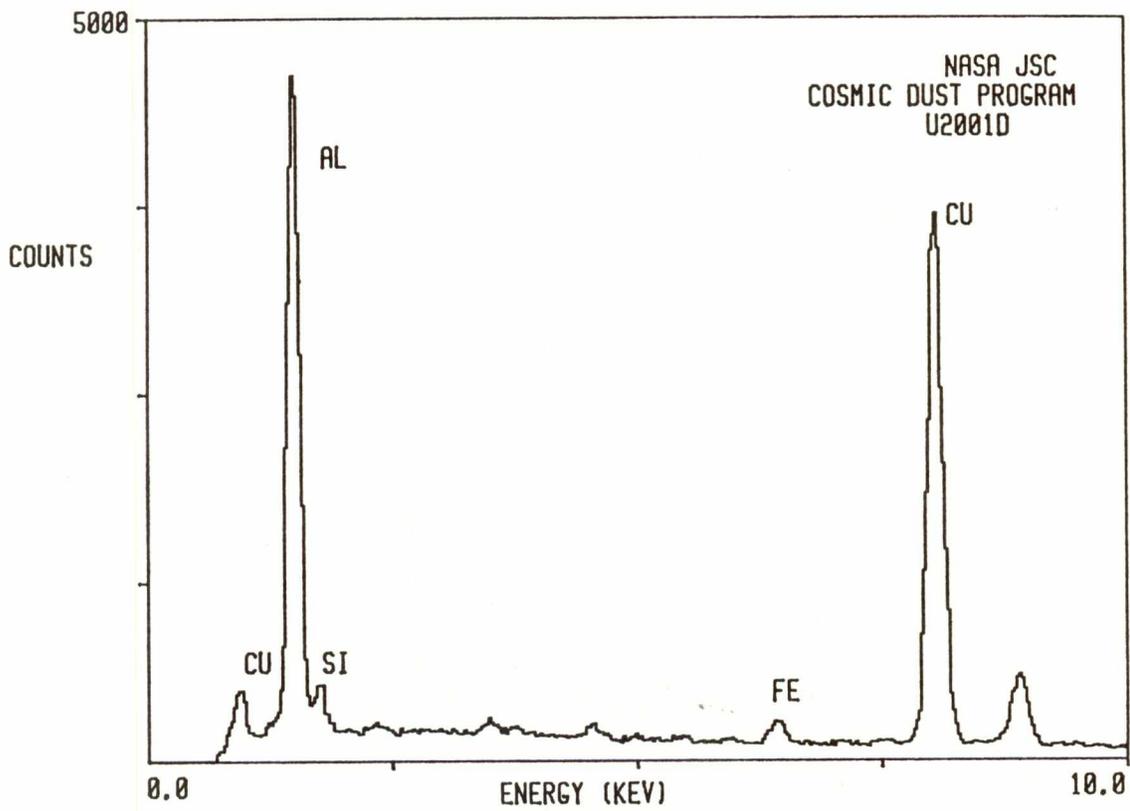
SIZE SHAPE TRANS.
8x8 E 0

COLOR LUSTER
Dk. Gray to Black SM

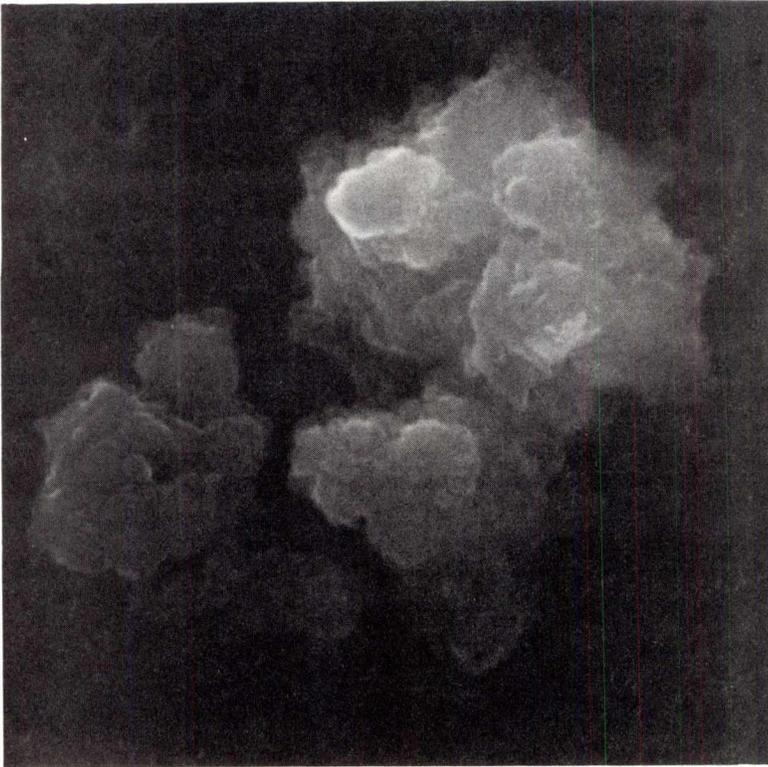
TYPE COMMENTS
TCA?

S-82-35214

U214D



U2001D15



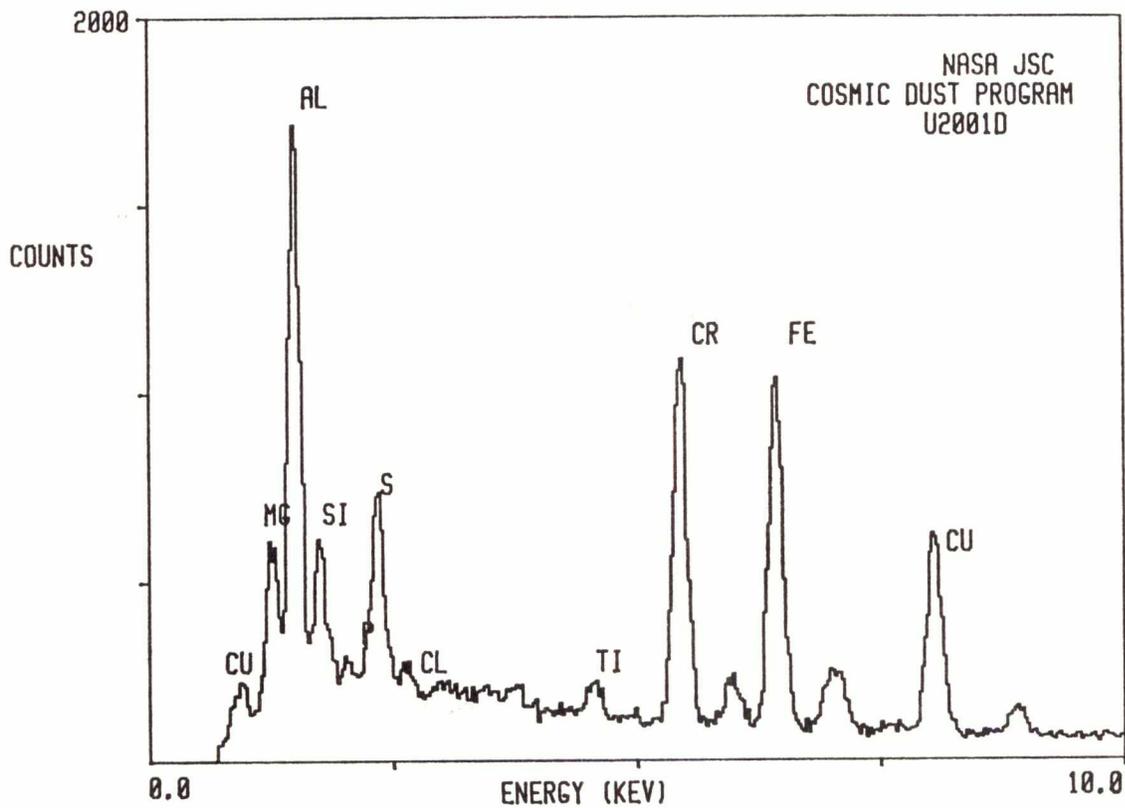
SIZE SHAPE TRANS.
7x8 I 0

COLOR LUSTER
Black D/SV

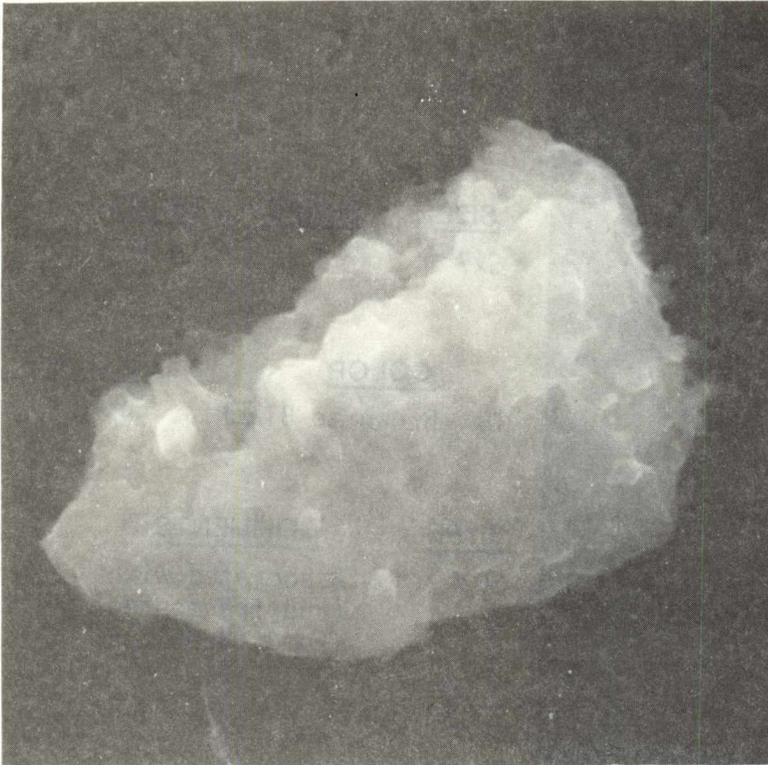
TYPE COMMENTS
TCA? Three fragments;
 "Size" applies
 to largest

S-82-35199

U215DA



U2001D16



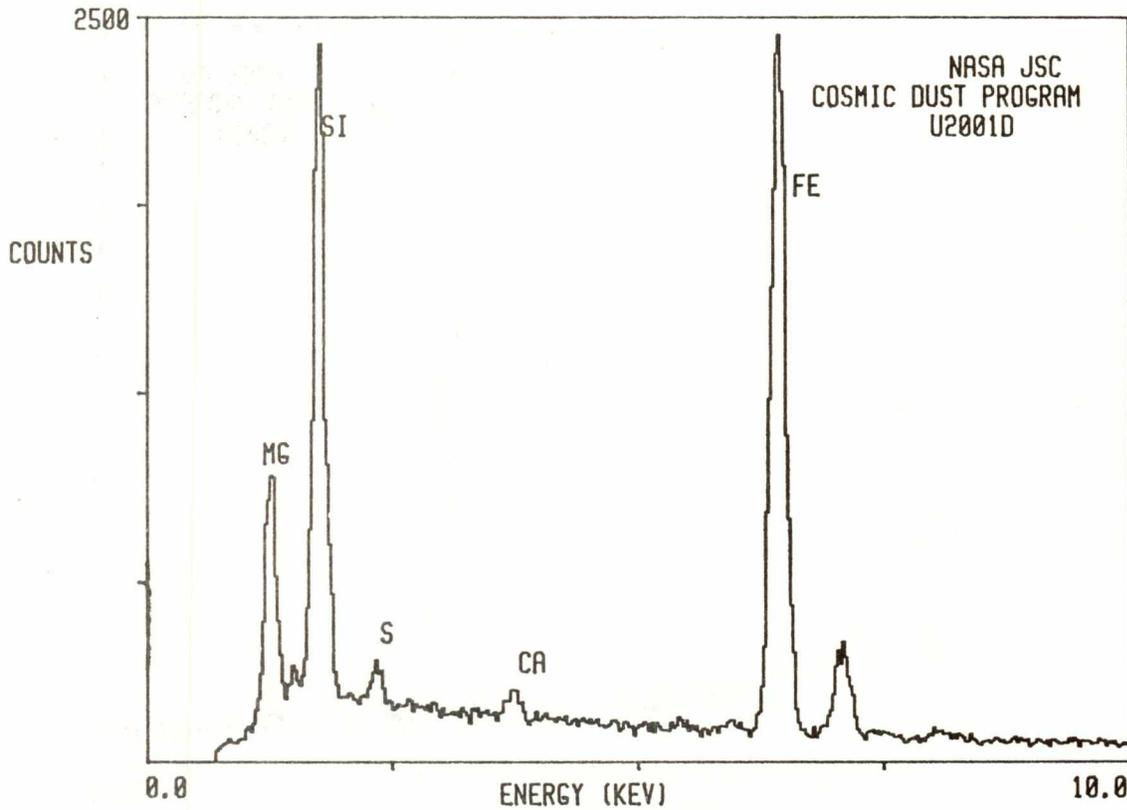
SIZE SHAPE TRANS.
8x12 I TL/0

COLOR LUSTER
Gray-Brown D/SV

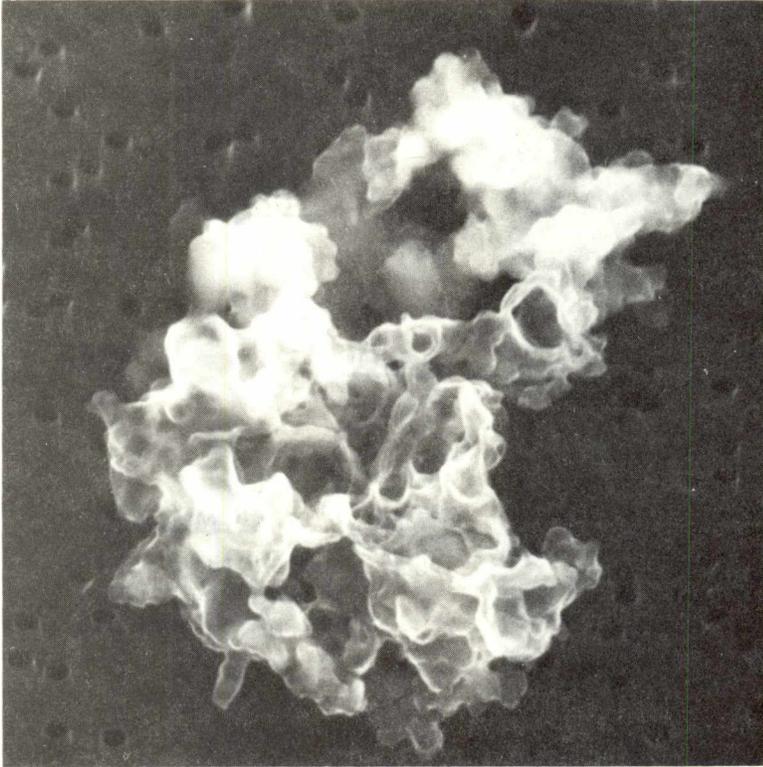
TYPE COMMENTS
C? Contains
opaque
inclusions (?)

S-82-35197

U216DA



U2001D18



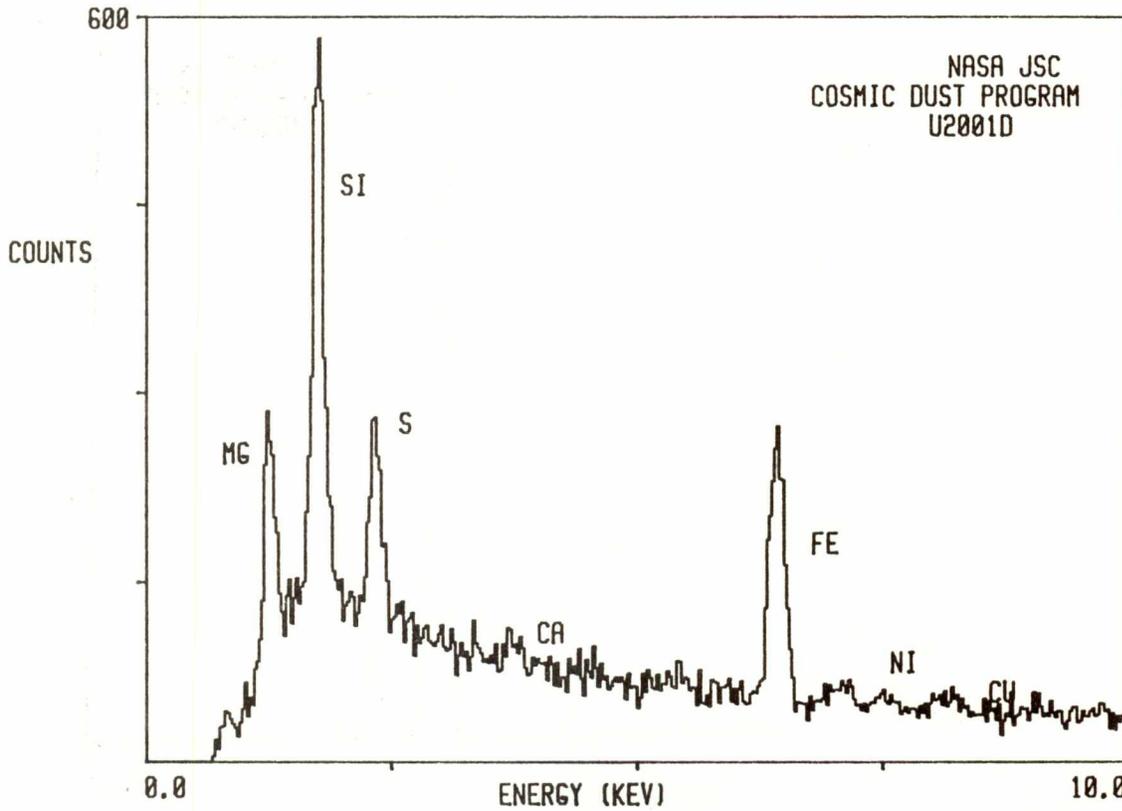
SIZE SHAPE TRANS.
6x9 I 0/TL

COLOR LUSTER
Dk. Brown to Black D/SM

TYPE COMMENTS
C? Associated with
 (and fragmented
 from?) U2001D16

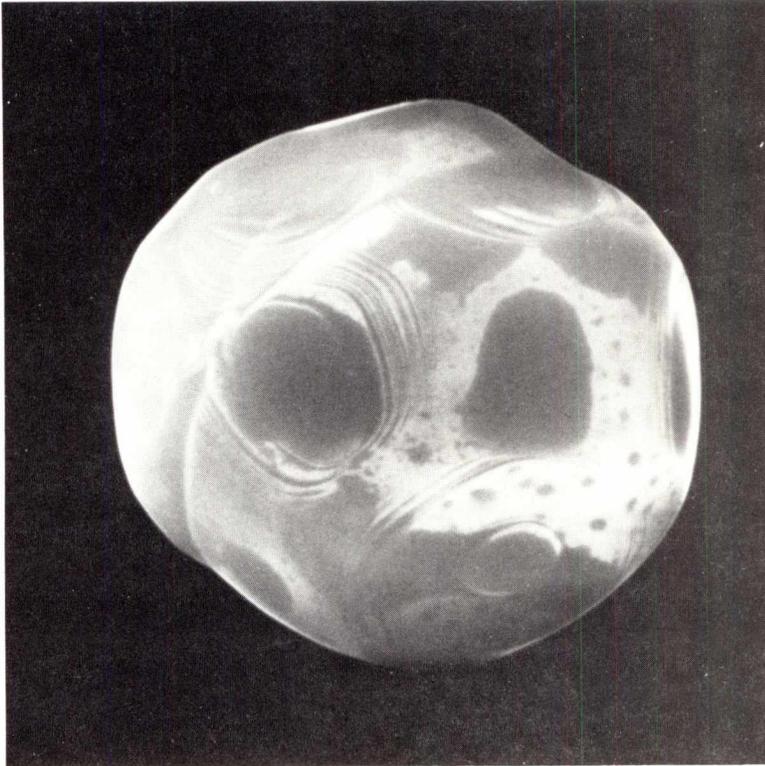
U216DC

S-82-35195



MOUNT U2001E

U2001E1



SIZE
11

SHAPE
S

TRANS.
T

COLOR
CL to Pale Yellow

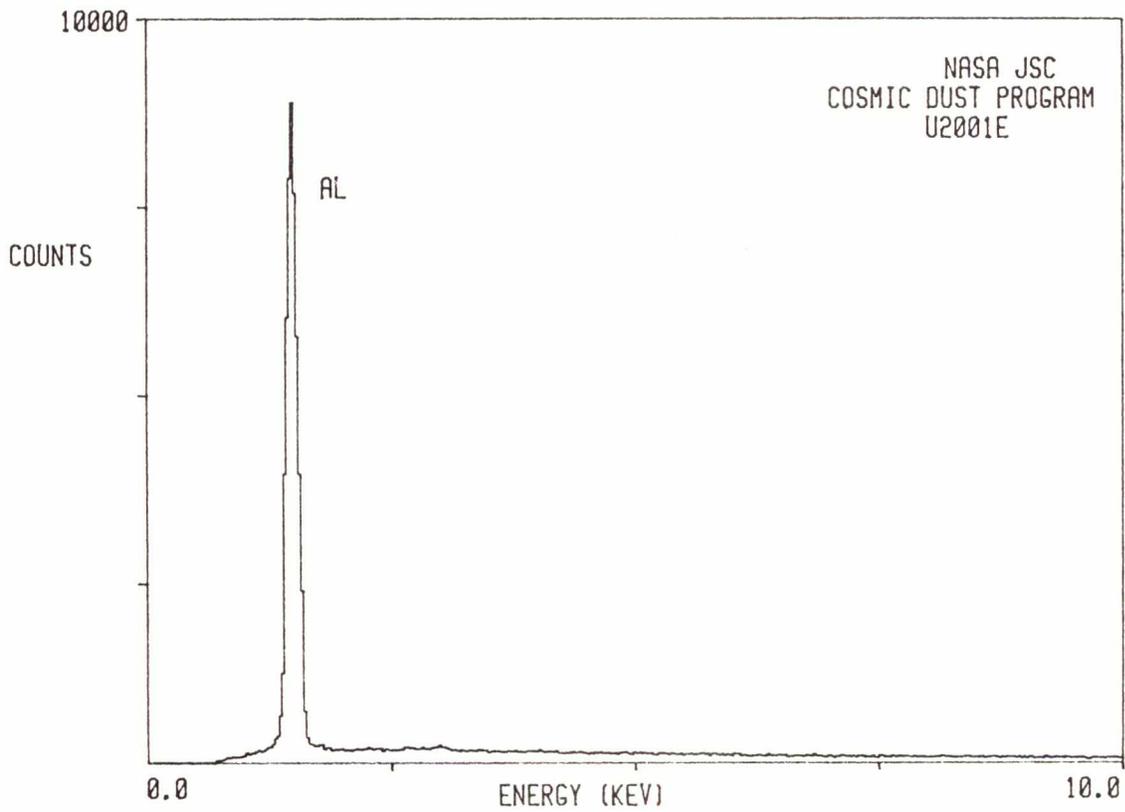
LUSTER
V

TYPE
AOS

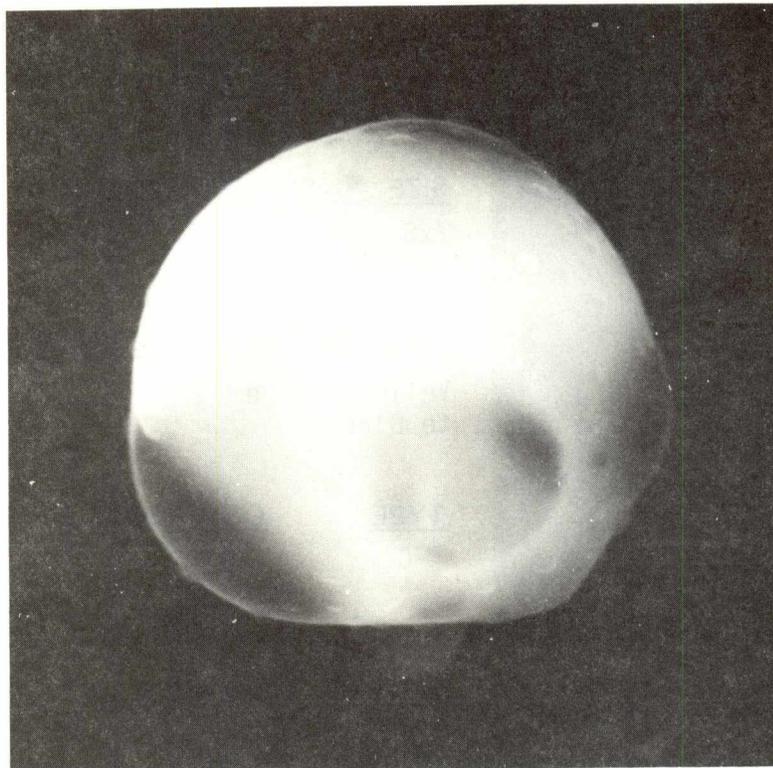
COMMENTS

S-82-34518

U201E



U2001E2



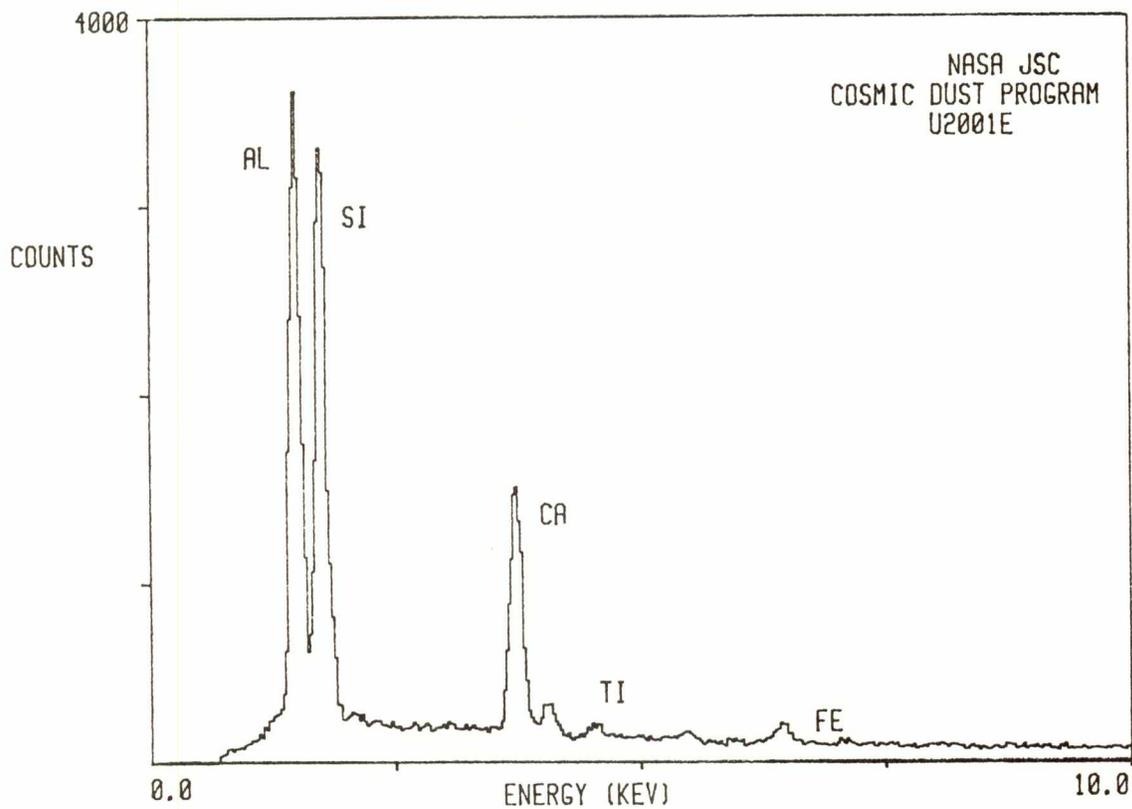
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
16	S	T

<u>COLOR</u>	<u>LUSTER</u>
CL to Pale Yellow-Gray	V

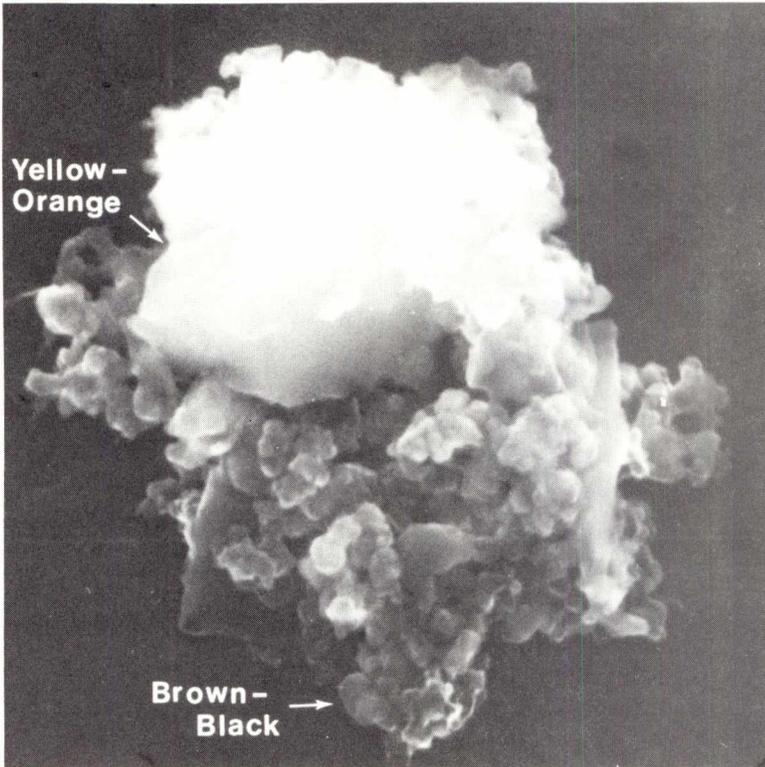
<u>TYPE</u>	<u>COMMENTS</u>
?	Unusual C?

S-82-34519

U202E



U2001E3



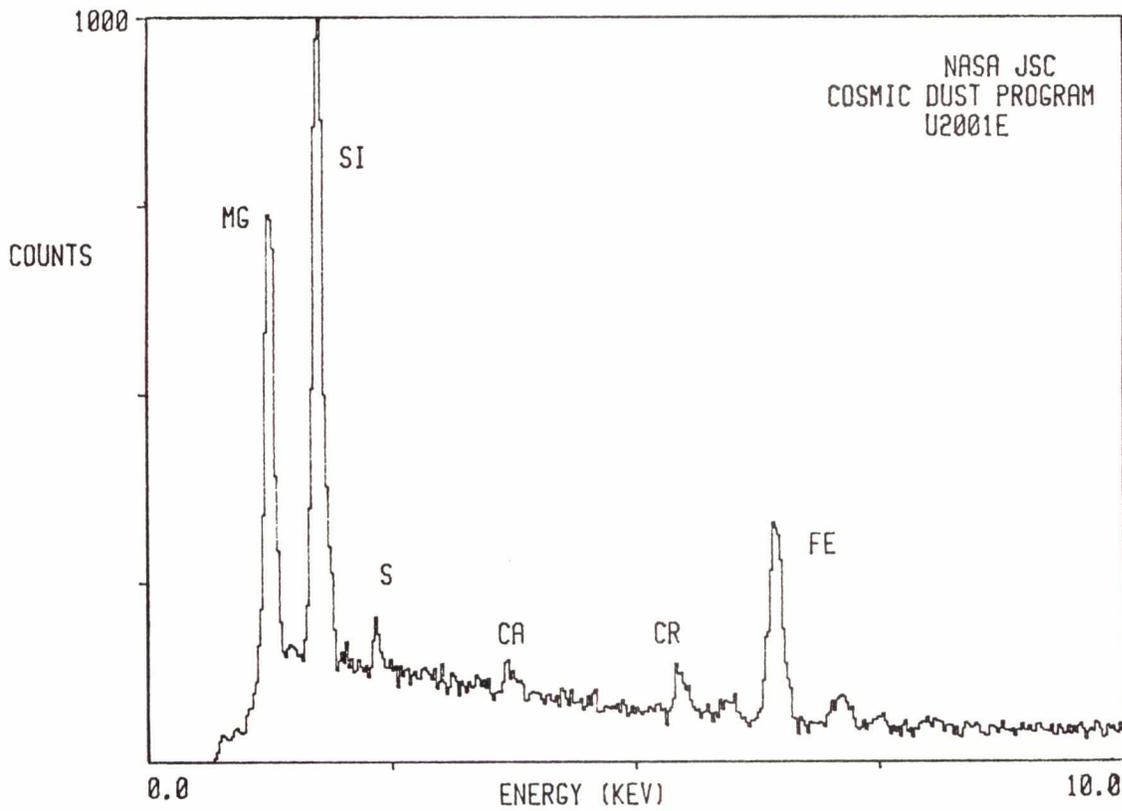
SIZE SHAPE TRANS.
 7x8 I 0/TL

COLOR LUSTER
 Yellow-Orange SV
 to Black

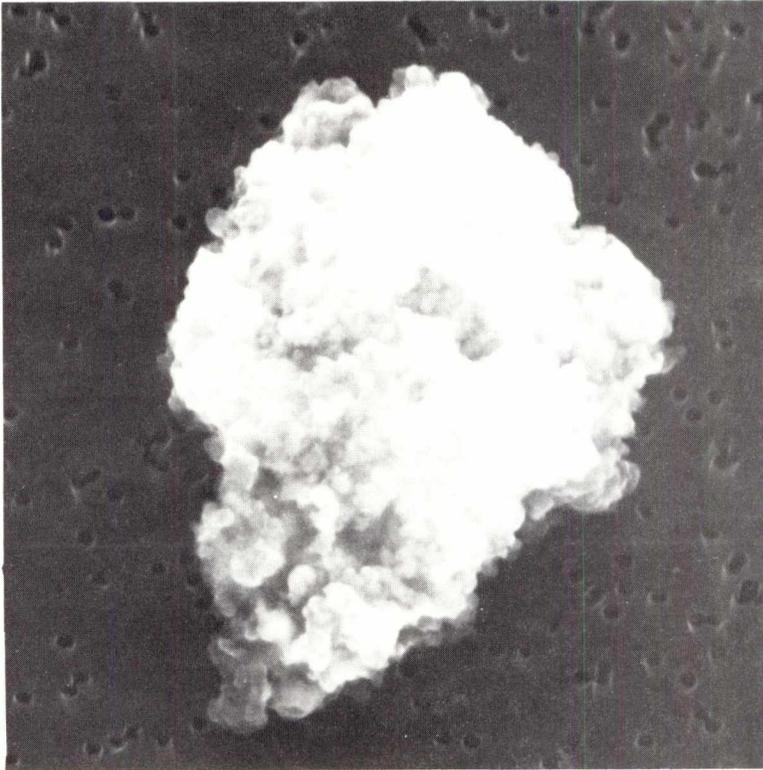
TYPE COMMENTS
 C

U203E

S-82-34520



U2001E5



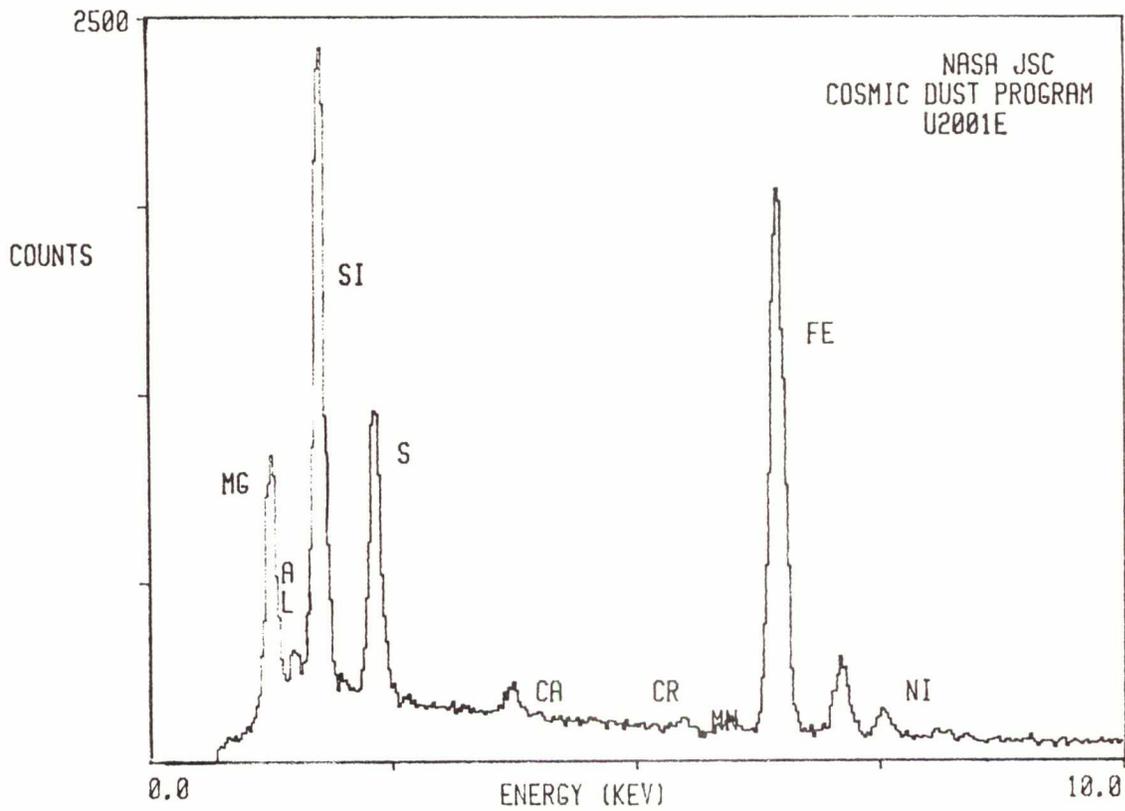
SIZE SHAPE TRANS.
9x13 I 0

COLOR LUSTER
Dk. Gray to Black D/SM

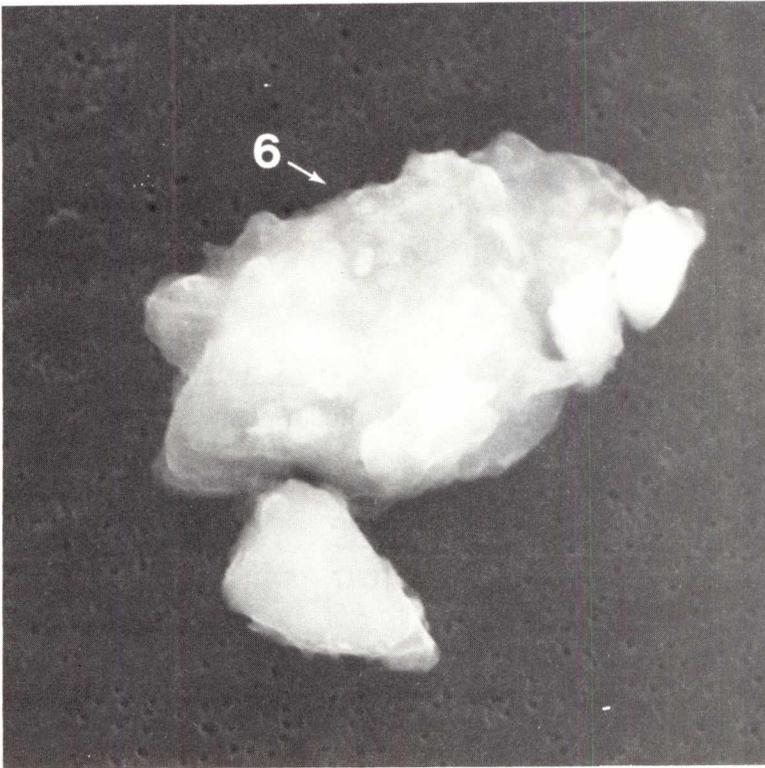
TYPE COMMENTS
C

U205E

S-82-34523



U2001E7



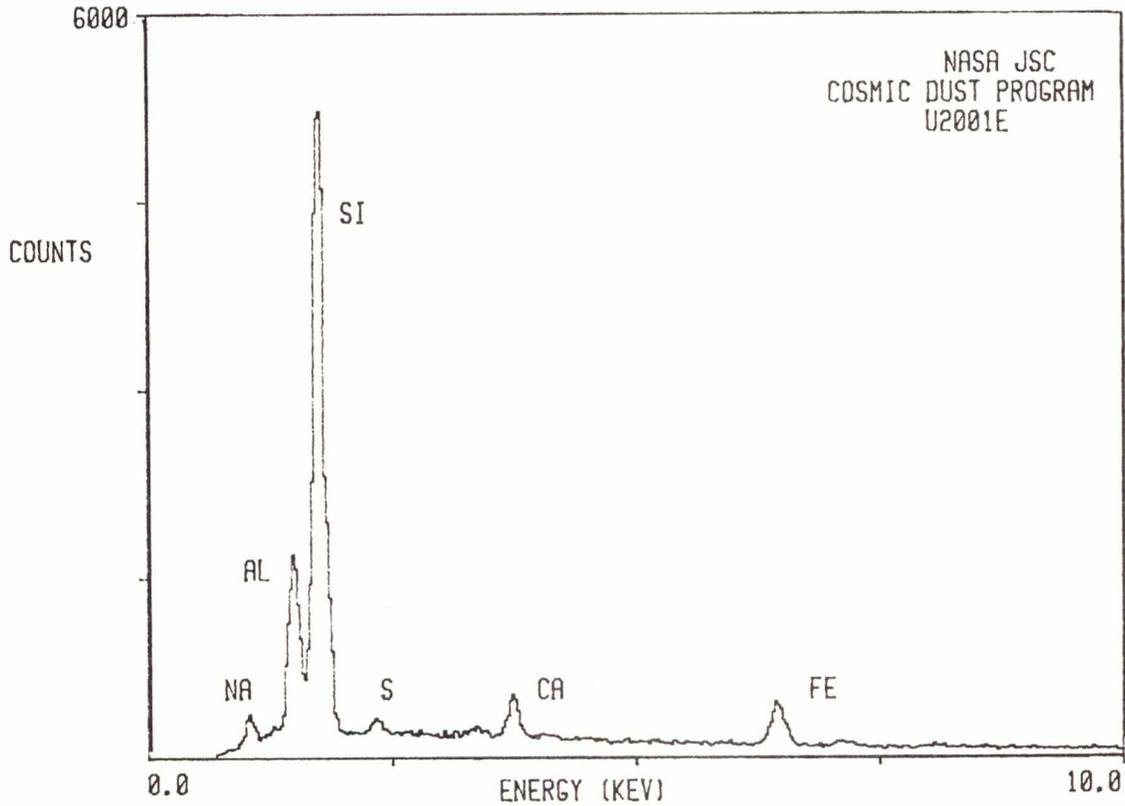
SIZE SHAPE TRANS.
5x7 I T

COLOR LUSTER
CL to Pale Gray V

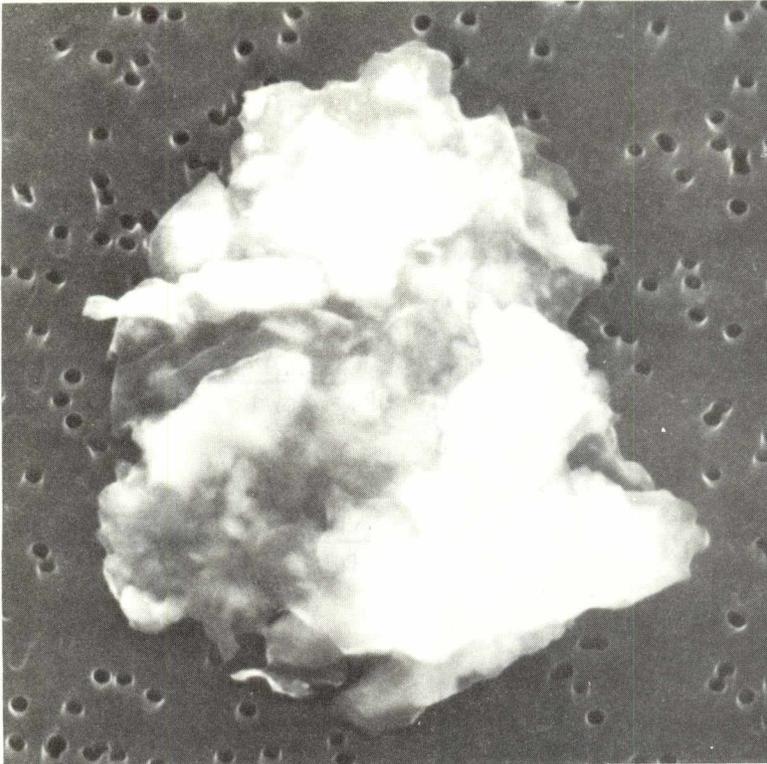
TYPE COMMENTS
TCN? Attached to
 U2001E6

U207E

S-82-34524



U2001E8



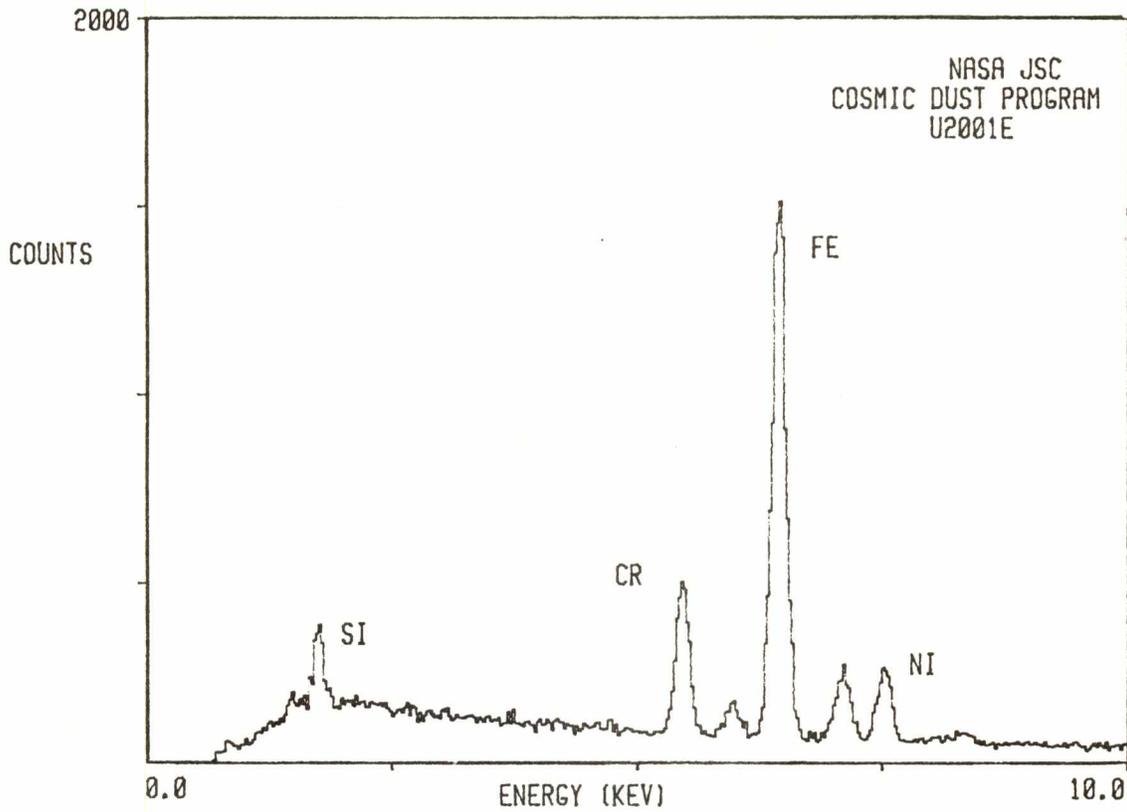
SIZE SHAPE TRANS.
7x8 I 0/TL

COLOR LUSTER
Dk. Brown to Black SM/M

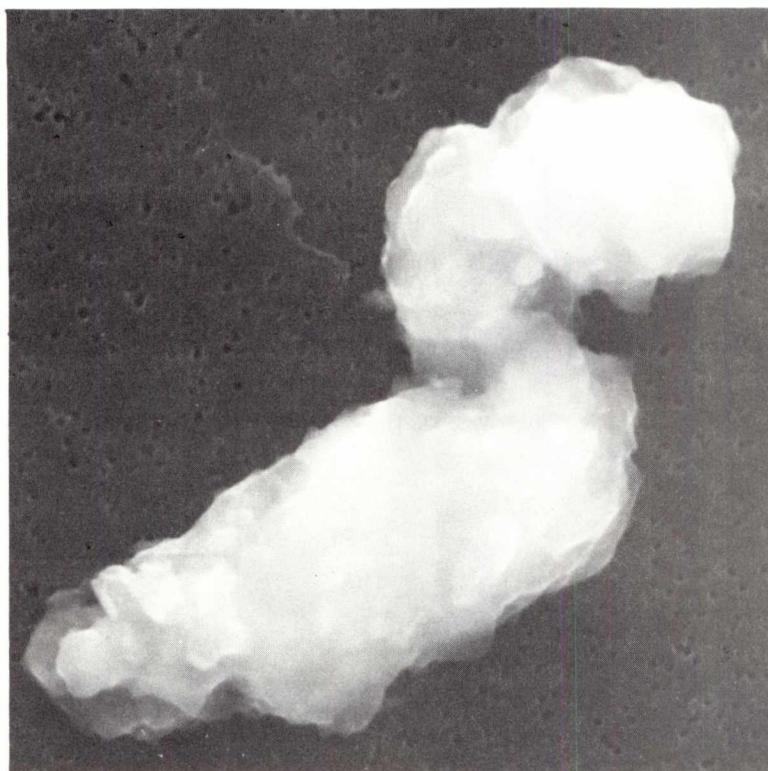
TYPE COMMENTS
TCA?

U208E

S-82-34525



U2001E9



SIZE
10x27

SHAPE
I

TRANS.
0

COLOR
Dk. Brown to Black

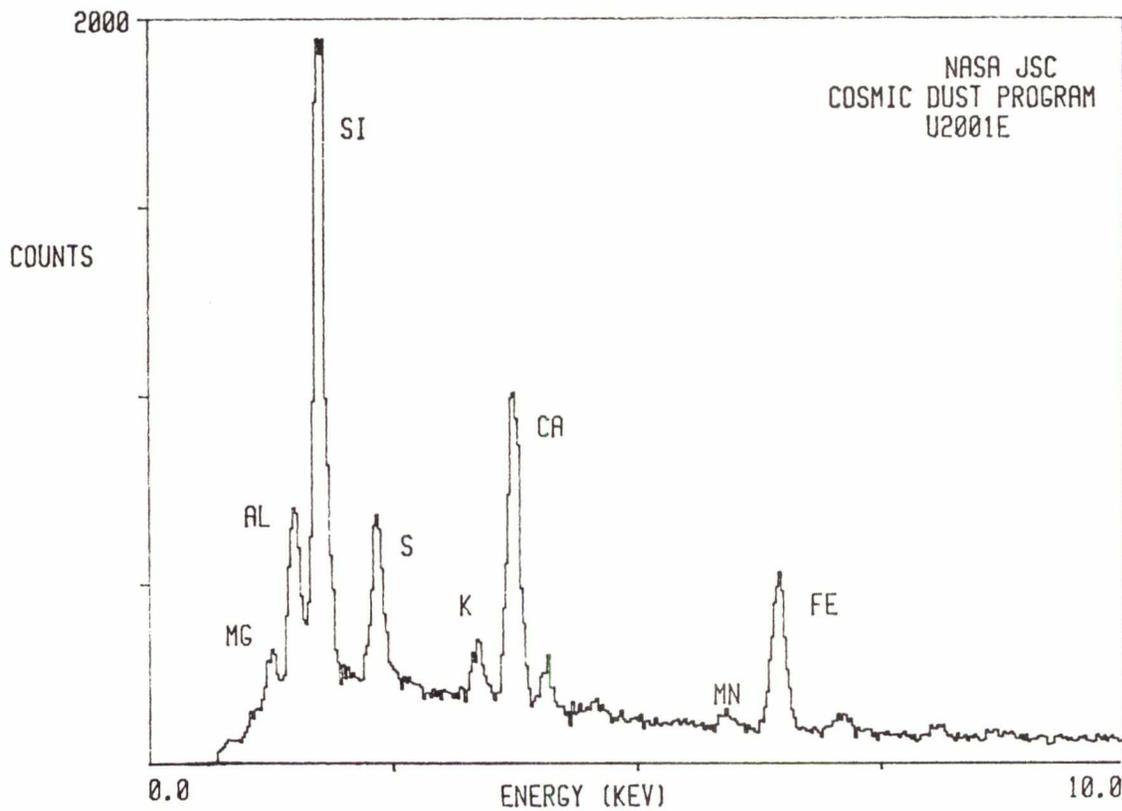
LUSTER
D/SM

TYPE
TCN?

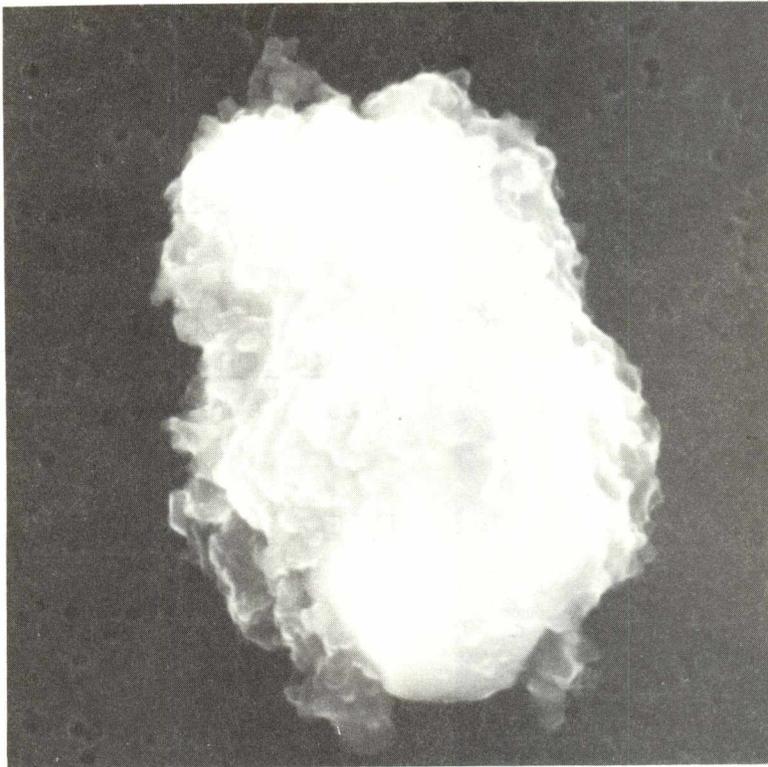
COMMENTS

U209E

S-82-34526



U2001E10

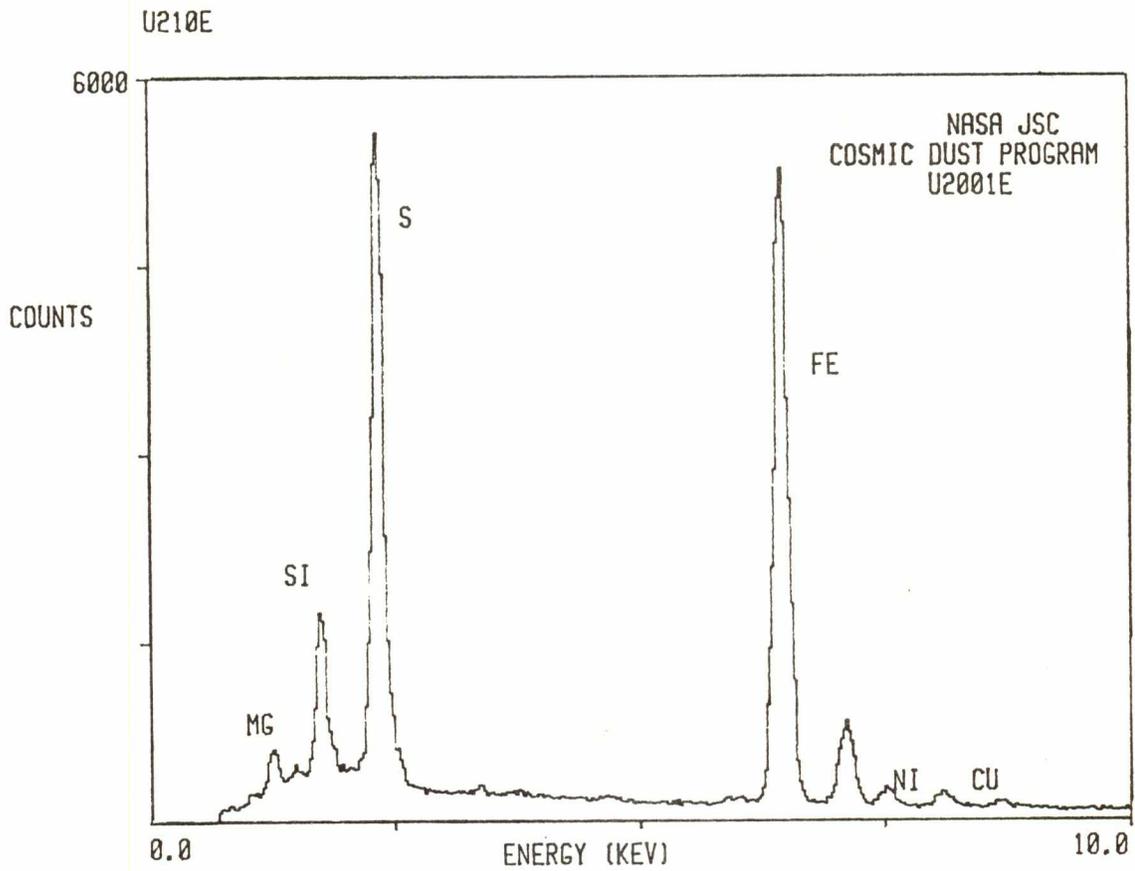


<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
9x13	I	0

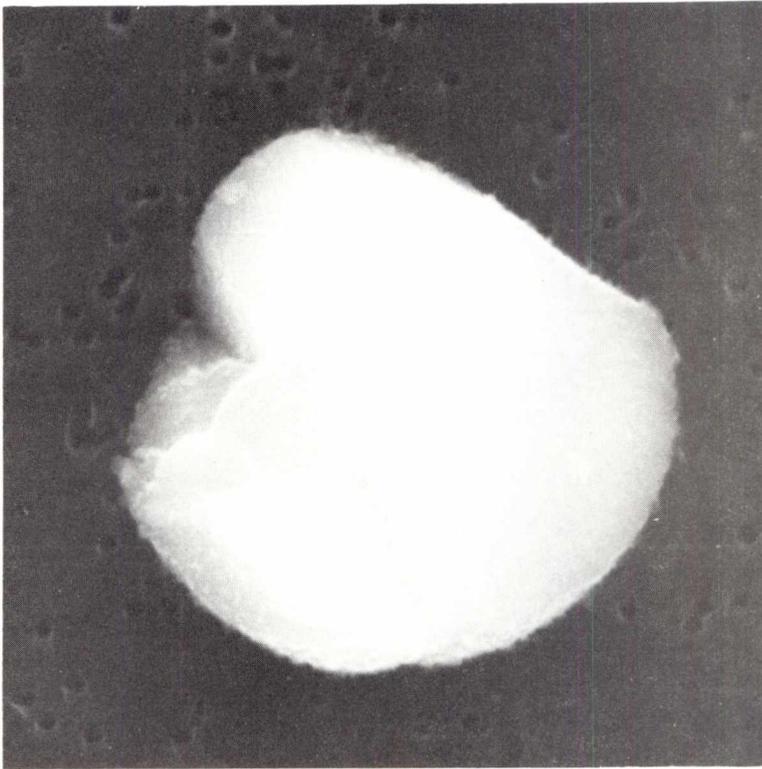
<u>COLOR</u>	<u>LUSTER</u>
Black	D/SM

<u>TYPE</u>	<u>COMMENTS</u>
C	

S-82-34527



U2001E11



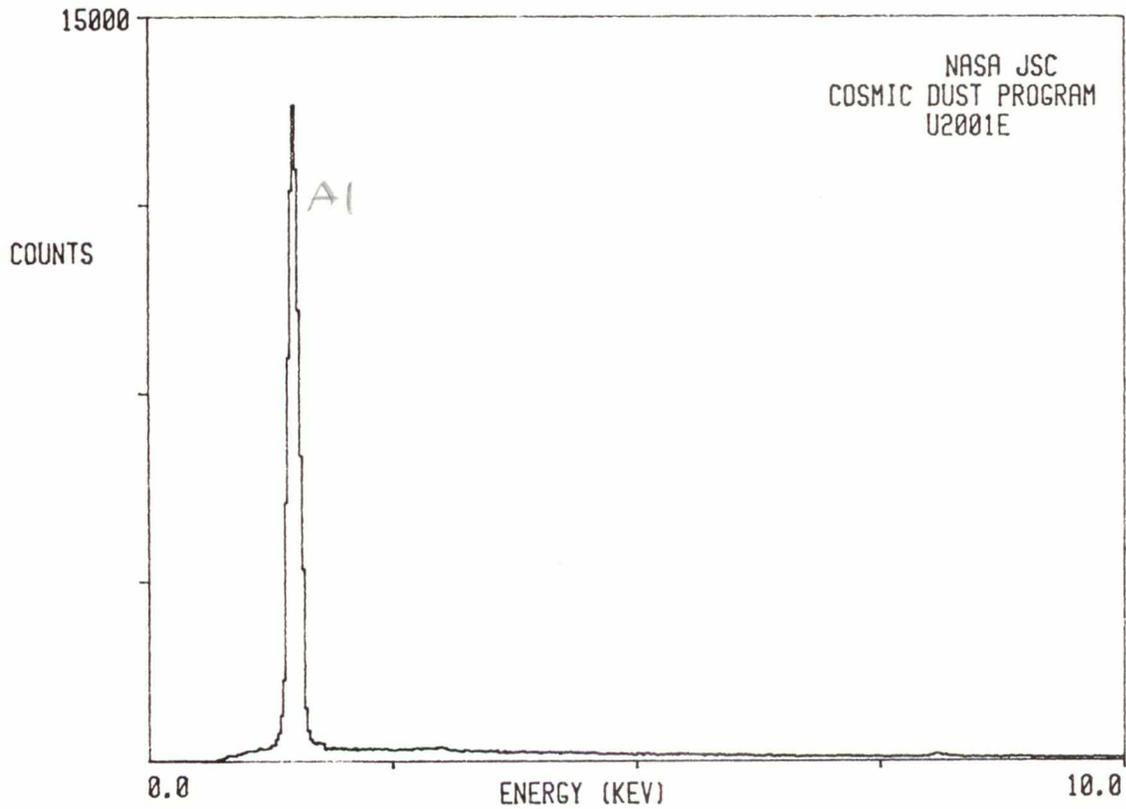
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
8	E/S	T

<u>COLOR</u>	<u>LUSTER</u>
CL to Pale Yellow	V

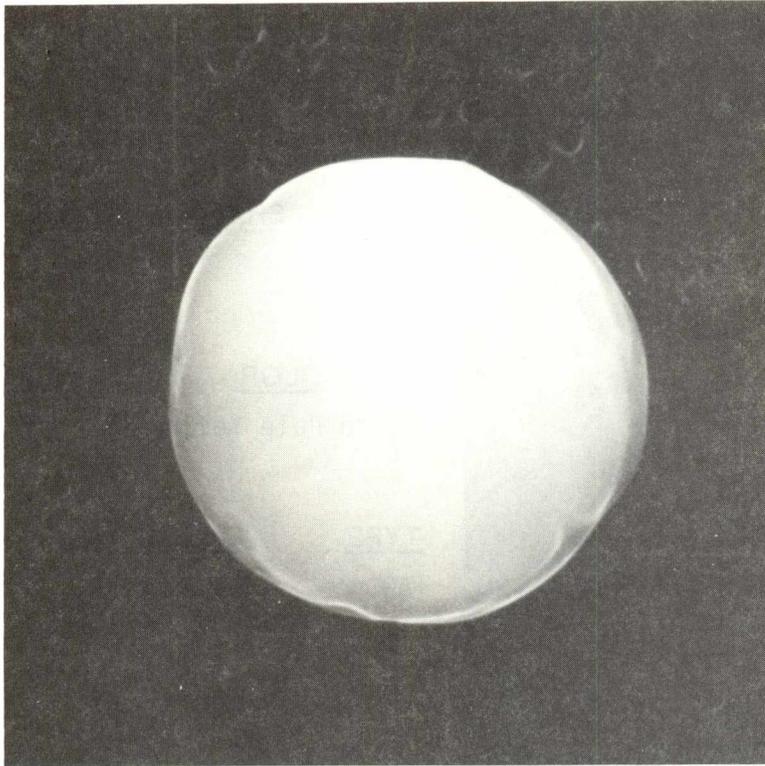
<u>TYPE</u>	<u>COMMENTS</u>
AOS	Broken sphere?

S-82-34528

U271E



U2001E12



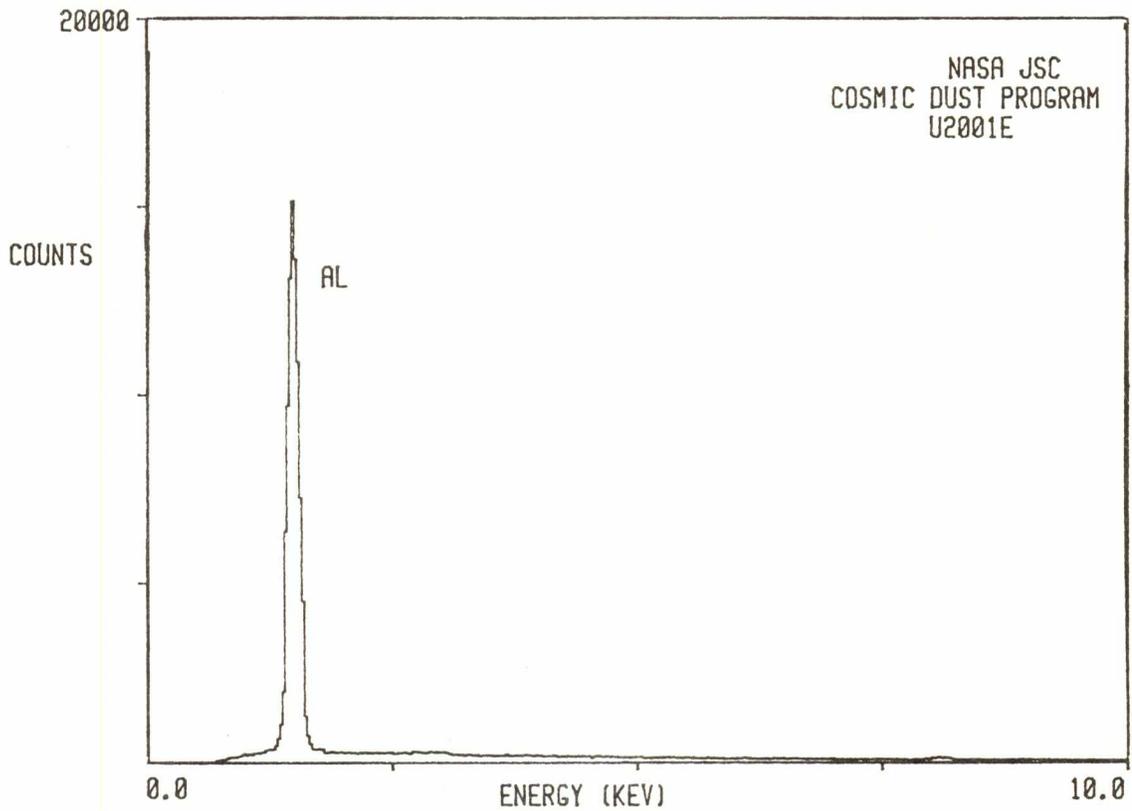
<u>SIZE</u>	<u>SHAPE</u>	<u>TRANS.</u>
6	S	T

<u>COLOR</u>	<u>LUSTER</u>
CL to Pale Yellow	V

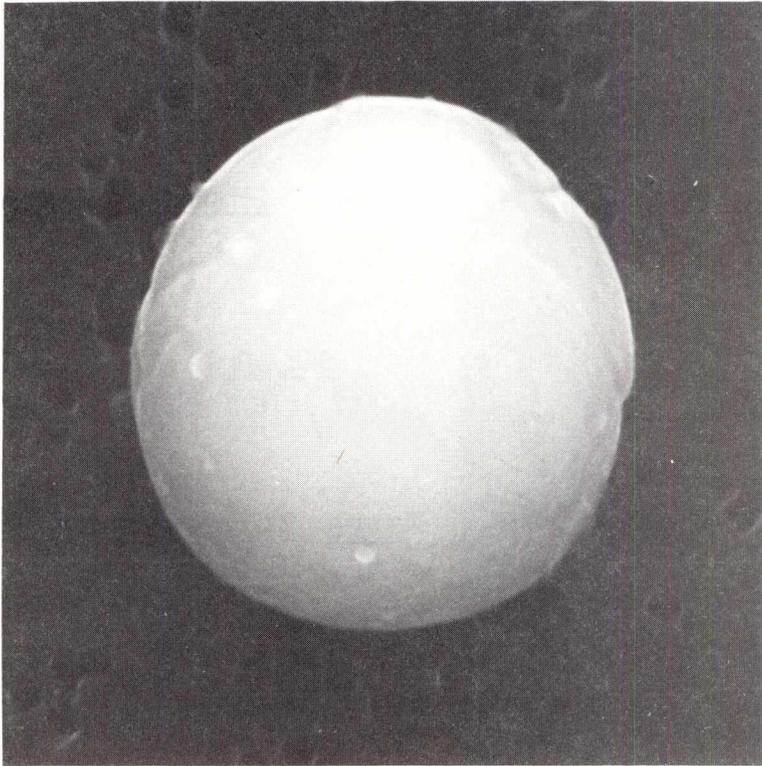
<u>TYPE</u>	<u>COMMENTS</u>
AOS	Associated with U2001E13

S-82-34529

U212E



U2001E13



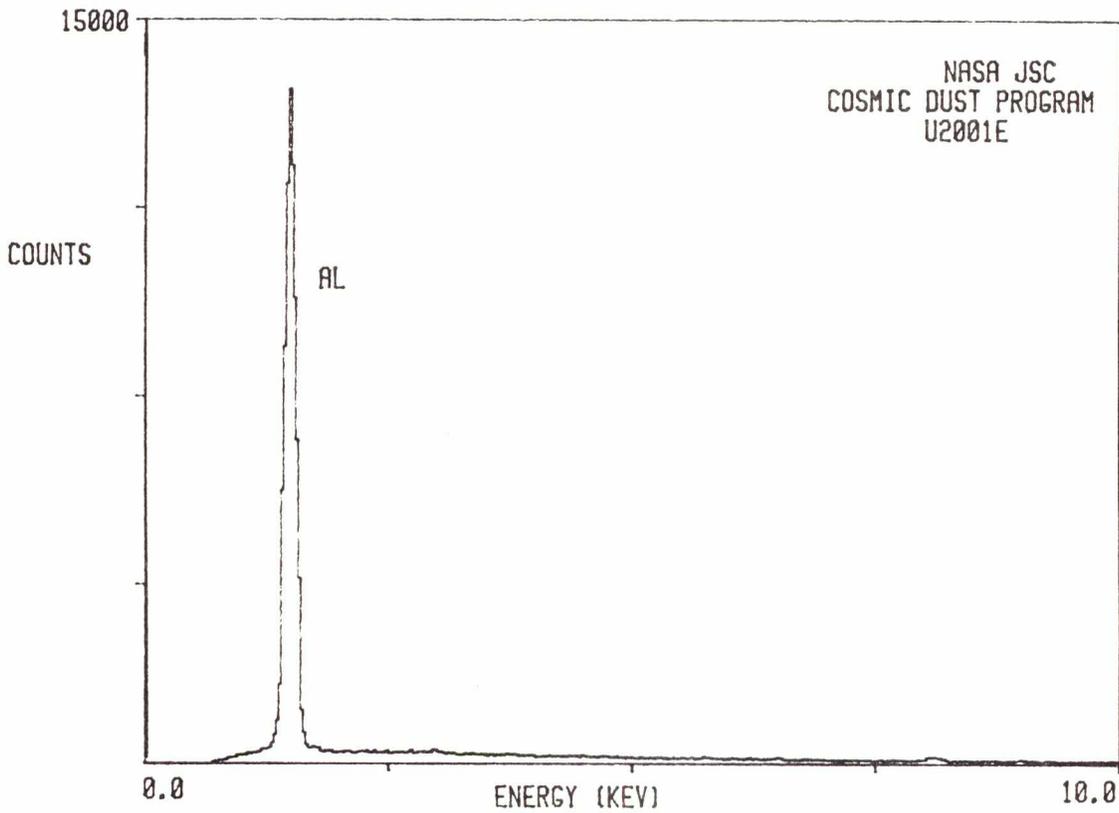
S-82-34530

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

<u>COLOR</u>	<u>LUSTER</u>
CL to Pale Yellow	V

<u>TYPE</u>	<u>COMMENTS</u>
AOS	Associated with U2001E12

U213E



U2001E14



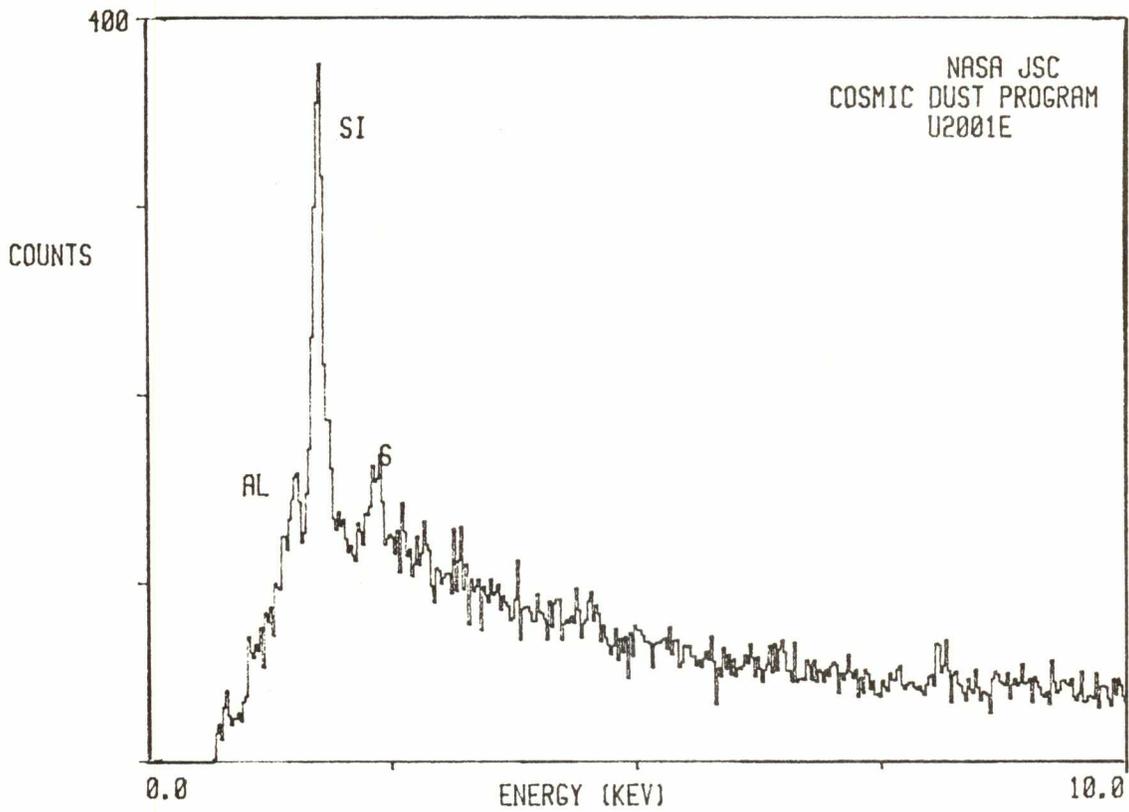
SIZE SHAPE TRANS.
11x15 I 0/TL

COLOR LUSTER
Dk. Brown to Black D/SM

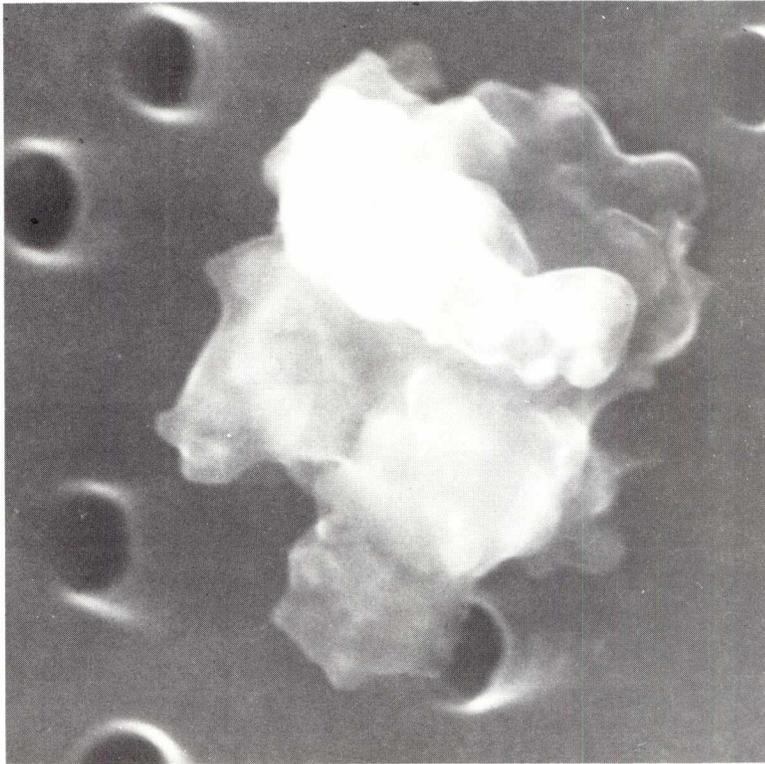
TYPE COMMENTS
TCA?

S-82-34531

U214E



U2001E15



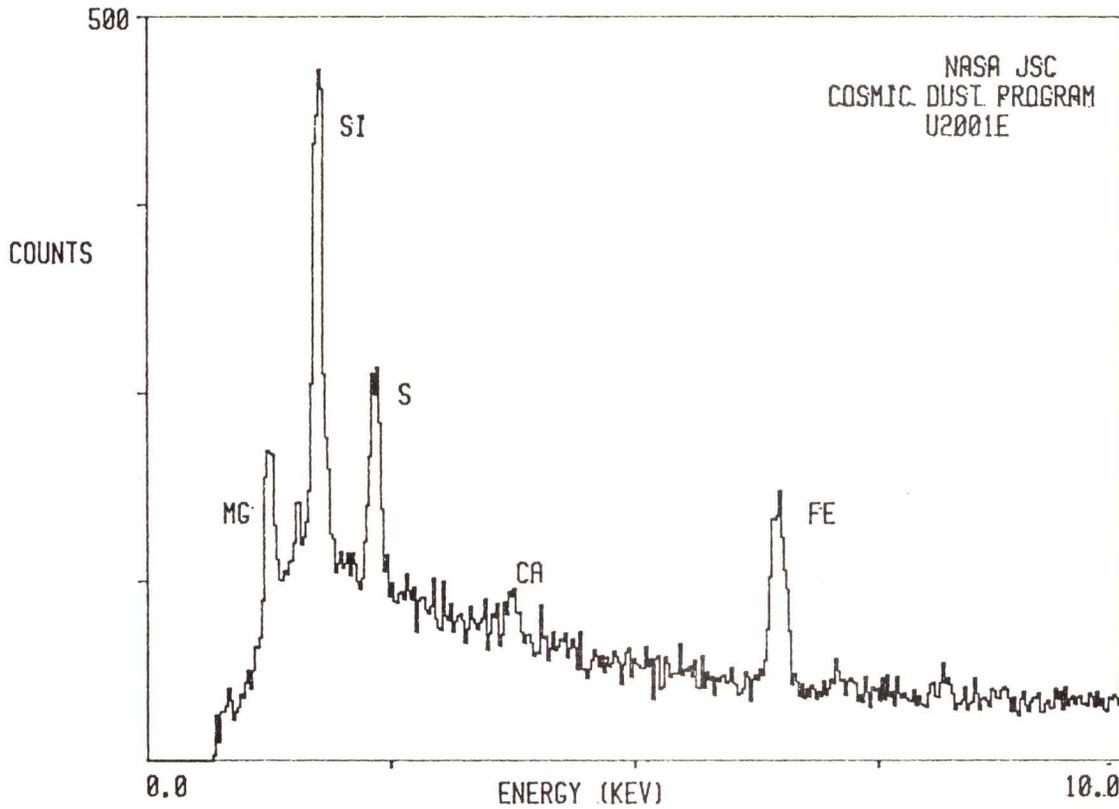
SIZE SHAPE TRANS.
~2 I 0

COLOR LUSTER
Black (?) D

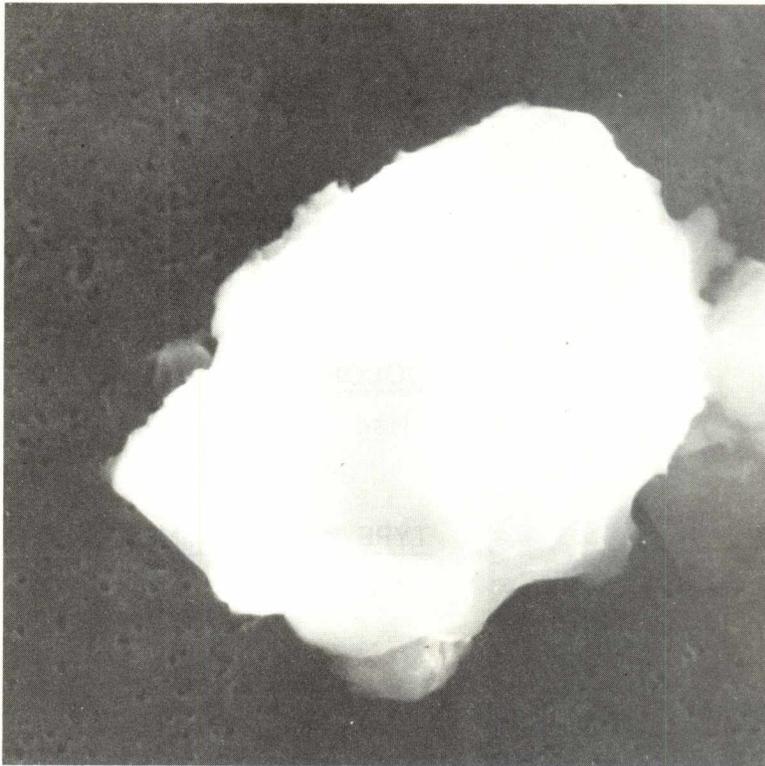
TYPE COMMENTS
C? One of 7
 ~equal-sized
 fragments

S-82-34532

U215EA



U2001E16



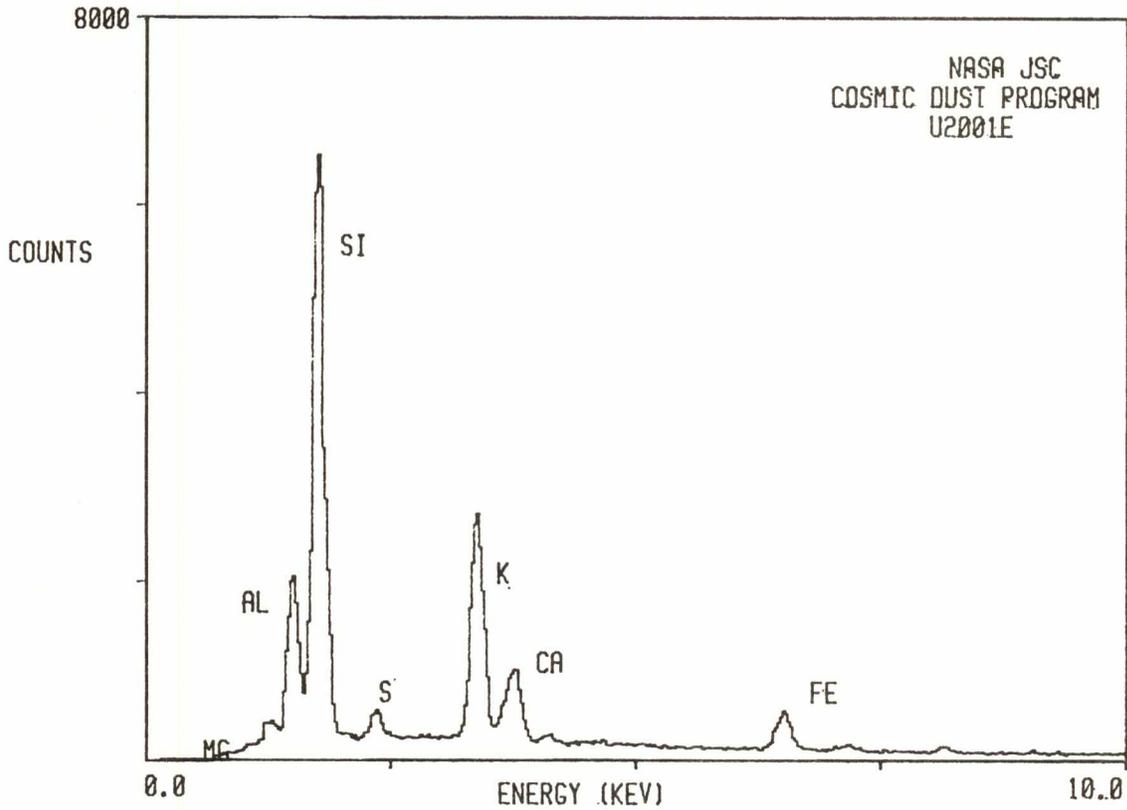
SIZE SHAPE TRANS.
17x18 I TL

COLOR LUSTER
CL to Pale V
Yellow-Gray

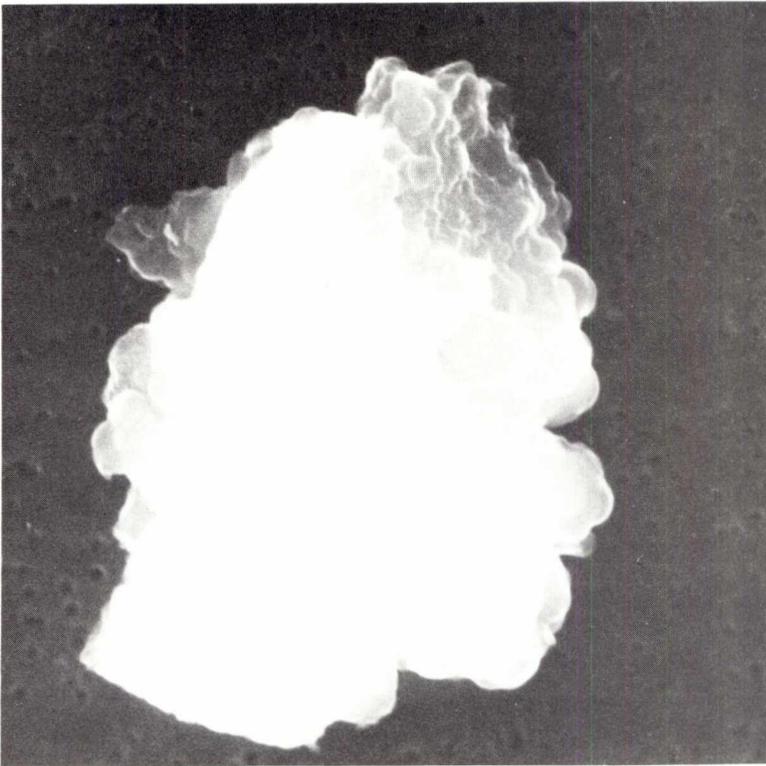
TYPE COMMENTS
TCN Largest of
3-4 frag-
ments

S-82-34539

U216E



U2001E17



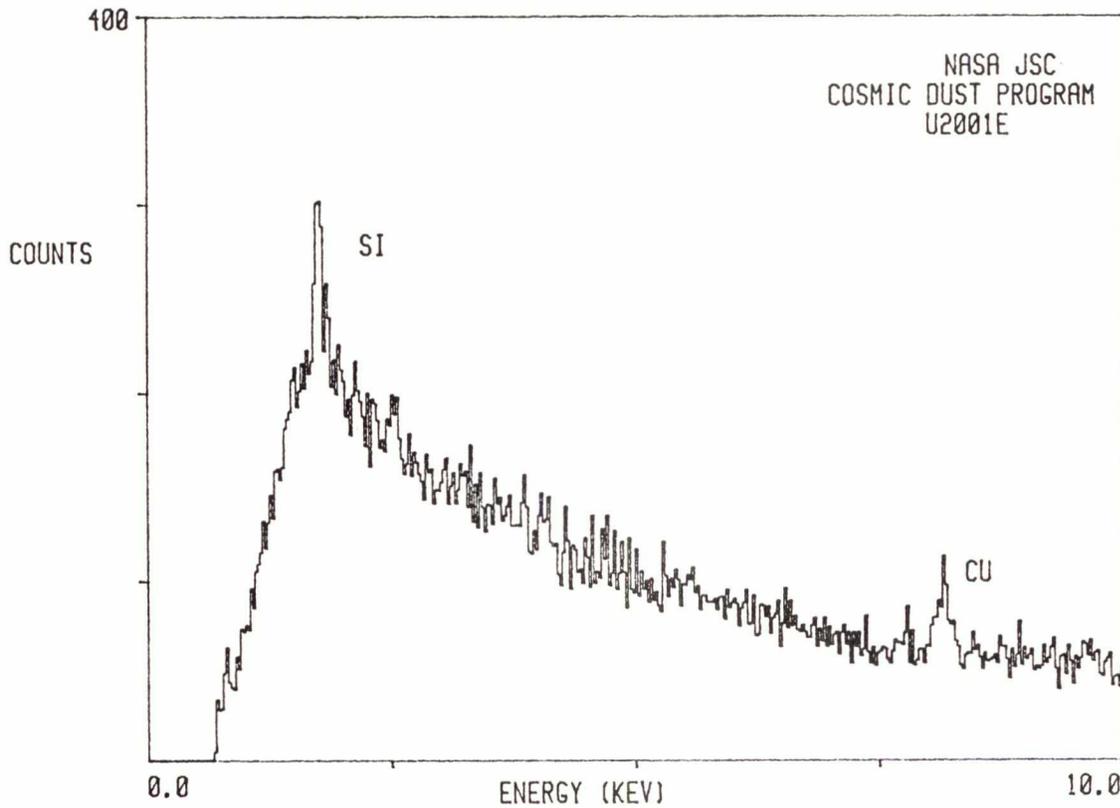
SIZE SHAPE TRANS.
14x17 I 0

COLOR LUSTER
Black SM

TYPE COMMENTS
TCA?

S-82-34543

U217E



U2001E18



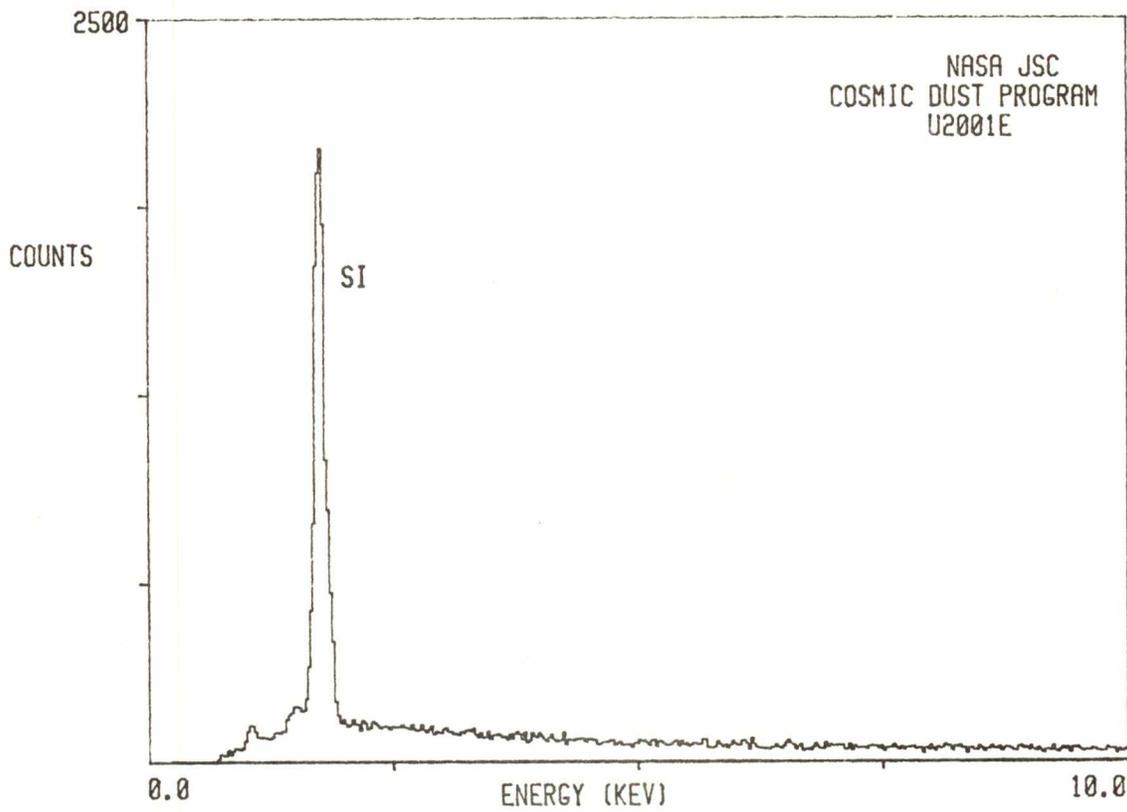
SIZE SHAPE TRANS.
4x9 I T

COLOR LUSTER
Pale Yellow SV

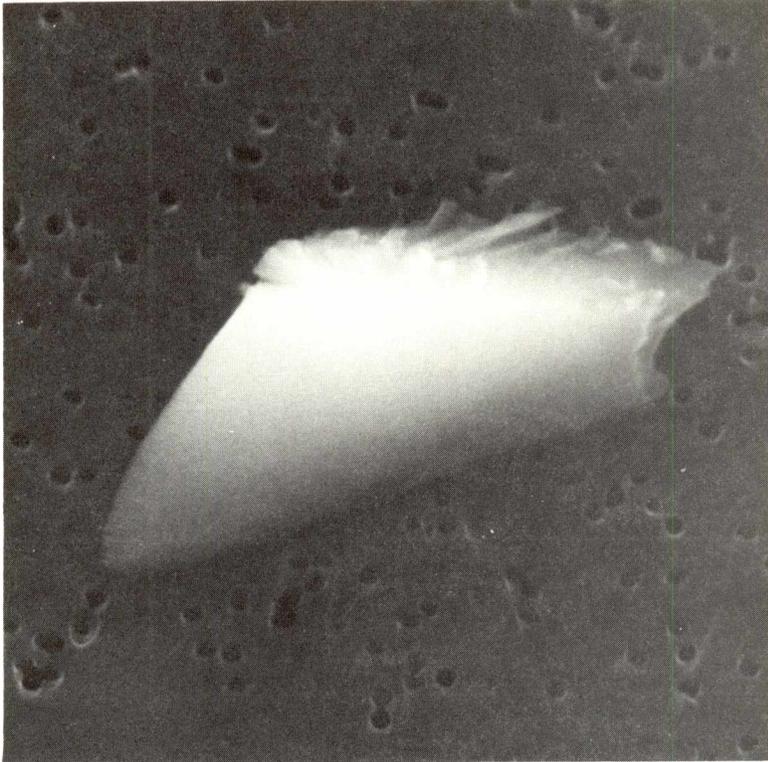
TYPE COMMENTS
TCN?

S-82-34544

U218E



U2001E20



SIZE SHAPE TRANS.
4x10 I T

COLOR LUSTER
CL V

TYPE COMMENTS
TCN?

S-82-34521

U203EA

