

COSMIC DUST CATALOG

(PARTICLES FROM COLLECTION FLAG U2034)

Planetary Materials Branch
Publication 77
JSC 22744

COMPILED BY
COSMIC DUST PRELIMINARY EXAMINATION TEAM (CDPET)

Volume 9
Number 1

NOVEMBER 1987

NASA

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

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(Particles from Collection Flag U2034)

Compiled by

Cosmic Dust Preliminary Examination Team (CDPET)*

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November, 1987

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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 97 particles retrieved from collection surface U2034. This surface was a flat plate "flag" (with a 30 cm² surface area) which was coated with silicone oil and then flown aboard a NASA U-2 aircraft during a series of flights that were made within west-central North America from April through August, 1985. This flag was installed in a specially constructed wing pylon 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 flag was exposed in the stratosphere by pilot command and then retracted into sealed storage containers prior to descent. In this manner, a total of 33.7 hours of stratospheric exposure was accumulated for flag U2034.

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 Nucleopore filter (0.4 μm 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 1-3 and 8. In these catalogs, EDS analysis was performed using the JEOL 100CX STEM operated at 40 kV. Only the EDS spectra exhibit differences that are likely to be noticed. These differences are a slightly higher background and more efficient excitation of high atomic number elements for EDS spectra collected at 40kV relative to those collected at 20kV. However, each catalog includes spectra of the same selected comparison standards, which allows comparison of spectra from one

catalog to the next to be made. 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), vitreous (V), and resinous (R). 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:

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, S, or Ni.

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.

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.)

?: 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.

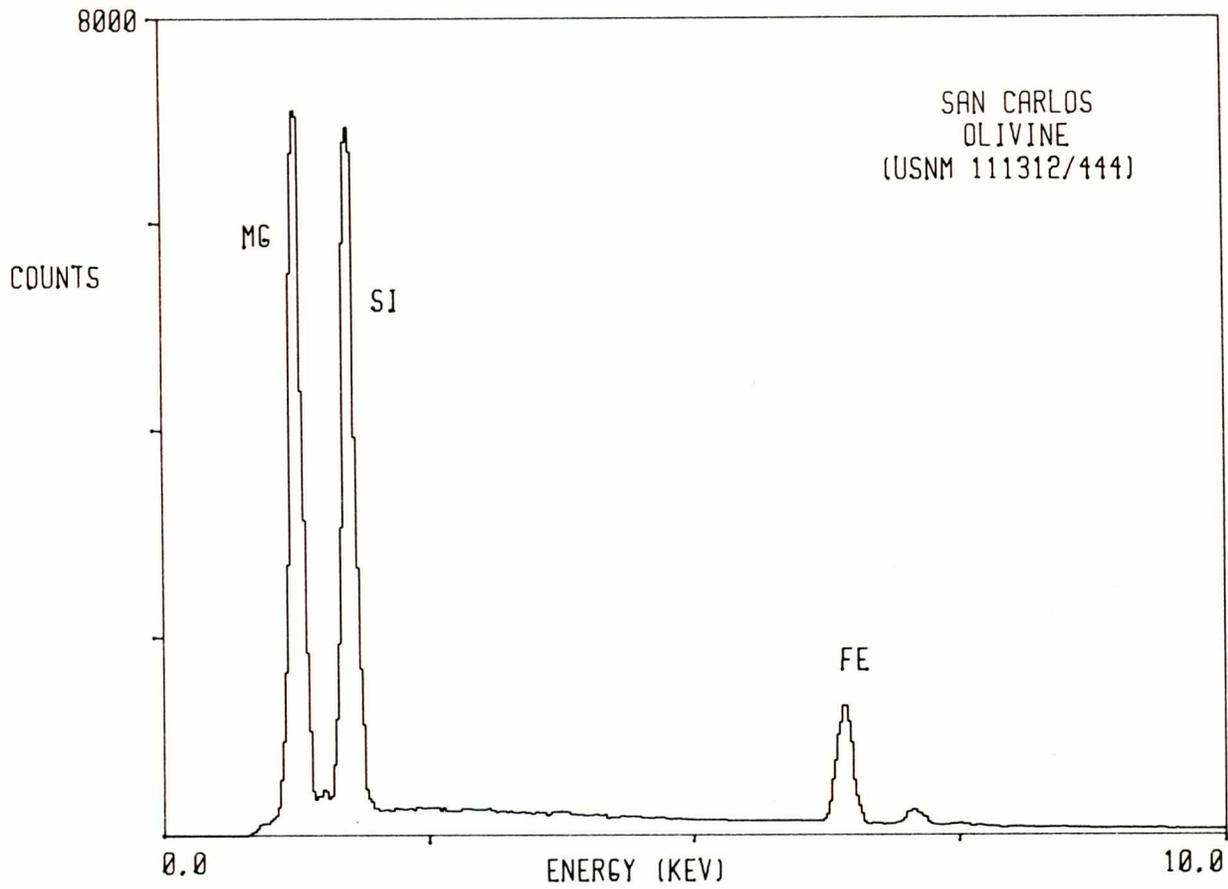
COMMENTS are included for particles with special features or histories. Particles lost during or after preliminary SEM examination, or particles with possible genetic relationships to other particles are noted here.

5. ANALYSES OF REFERENCE MATERIALS

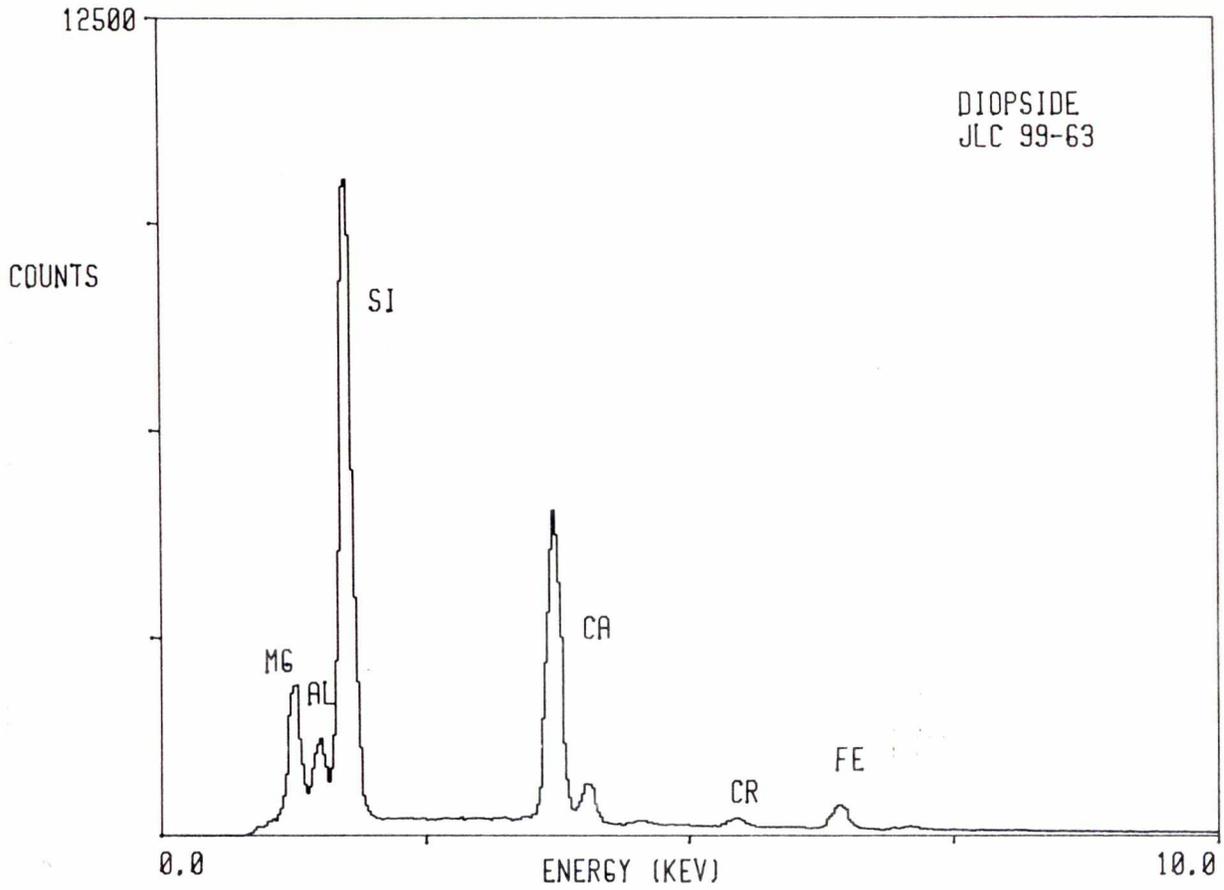
The usefulness of the SEM images and EDS spectra provided for particles in this catalog is enhanced by comparison with similar data products obtained for mineral standards of known composition. Accordingly, a typical EDS spectrum is presented for each of three standard minerals prepared as polished grain mounts (San Carlos olivine, USNM 111312/444; diopside JLC 99 63; Kakanui hornblende, USNM 143965; Allende Meteorite Bulk Powder, NMNH 3529). 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 1-3 and 8 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

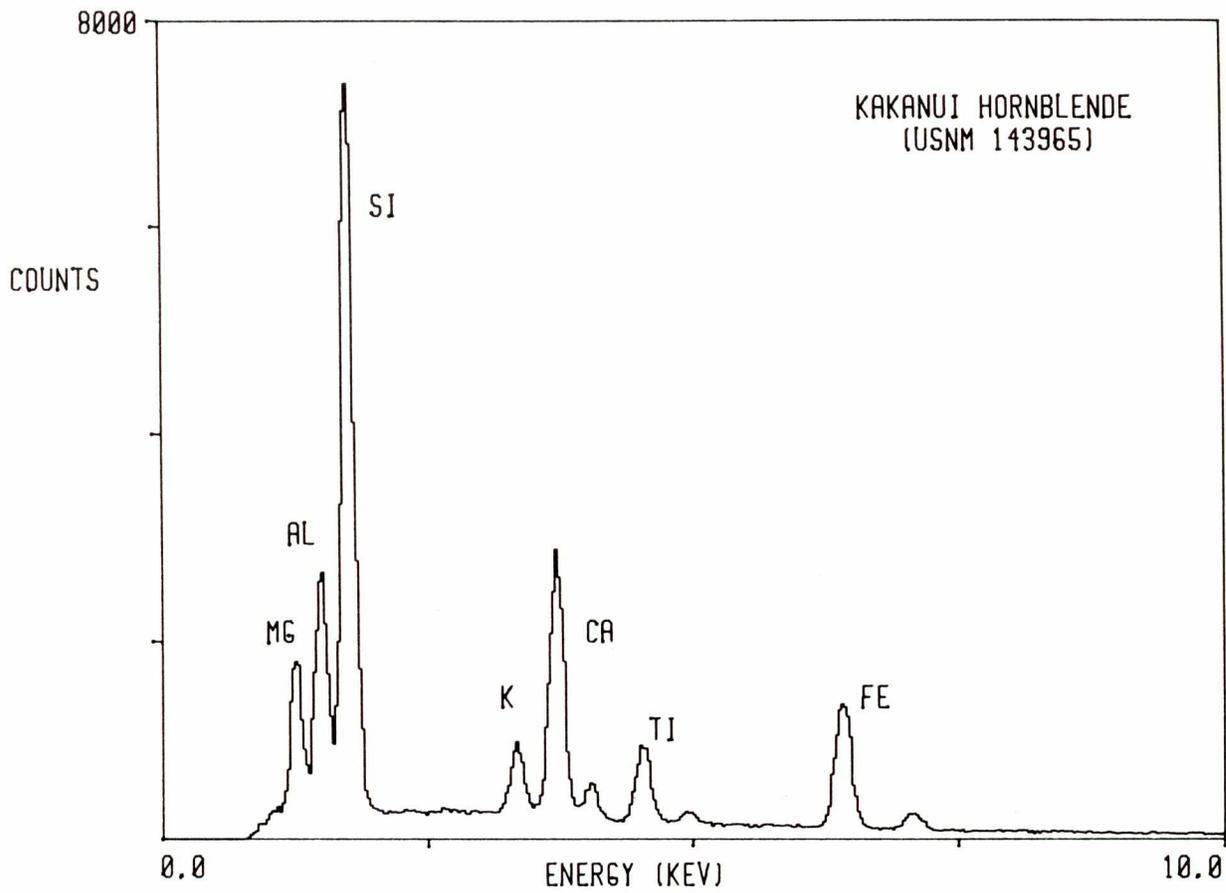
obtained at 20 kV and the other at 40 kV, as presented in Cosmic Dust Catalogs 1-3 and 8 (only spectra collected at 20kV are presented in this catalog). In the 20 kV spectrum, the Si peak is more intense than the principal peak of Fe whereas the opposite is true for the 40 kV spectrum. In general, the 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 1-3 and 8. 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 40 kV spectra with 20 kV spectra. 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.



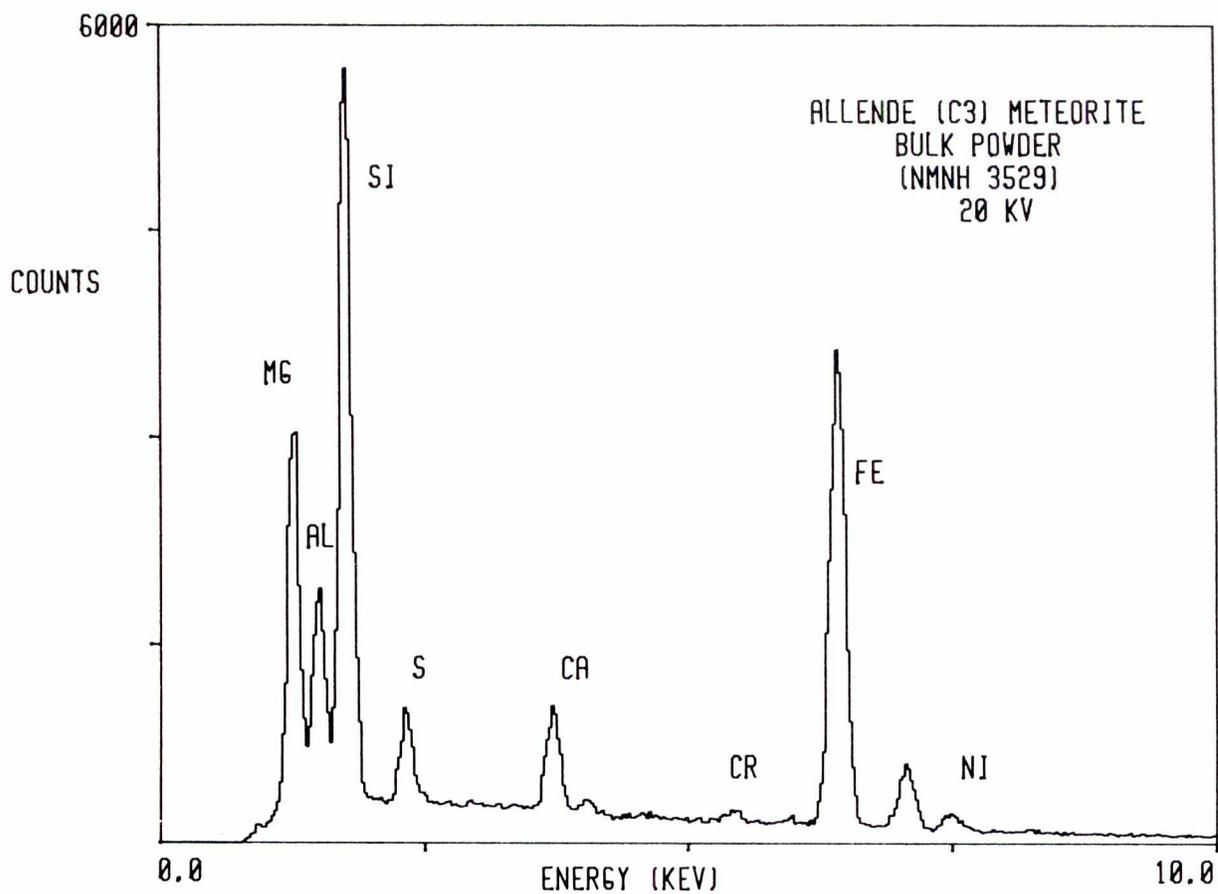
WEIGHT %													TOTAL
SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	NiO	MnO	MgO	CaO	Na ₂ O	K ₂ O	H ₂ O	
40.81	-	-	-	-	9.55	0.37	0.14	49.42	<0.05	-	-	-	100.29



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	9.96	1.80	2.34	0.04	0.07	16.05	19.64	1.39	-	-	99.99



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	
40.37	4.72	14.90	-	3.30	7.95	-	0.09	12.80	10.30	2.60	2.05	0.94	100.02



ALLENDE (C3) METEORITE
 BULK POWDER
 (NMNH 3529)
 20 KV

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) 483-5128
Code SN2	
NASA/Johnson Space Center	FTS: 525-5128
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:

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

Norm La Fleur and coworkers (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.

8. PARTICLE TABLE OF CONTENTS

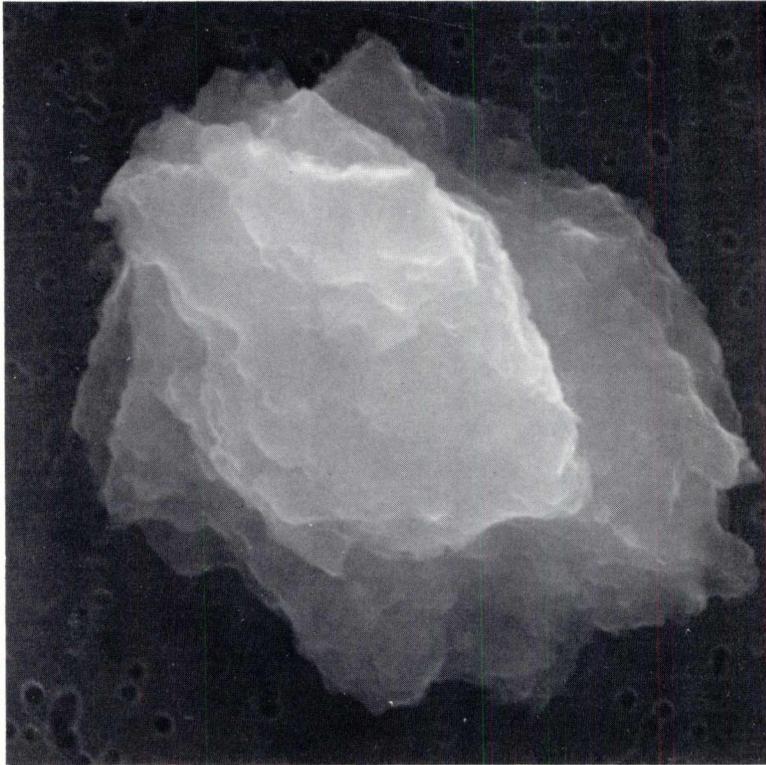
Since particles are arranged in this catalog by type, rather than sequentially by mount and number as in previous catalogs, we include a sequential listing of particles and the page on which they may be found, for the user's reading pleasure.

<u>PARTICLE</u>	<u>PAGE</u>	<u>PARTICLE</u>	<u>PAGE</u>	<u>PARTICLE</u>	<u>PAGE</u>	<u>PARTICLE</u>	<u>PAGE</u>
A1	68	B4	52	C14	84	E1	86
A4	20	B5	23	C15	31	E2	11
A5	69	B6	24	C16	32	E3	12
A6	96	B7	53	C17	6	E4	60
A7	70	B8	25	D1	7	E5	39
A8	50	B9	78	D2	8	E6	87
A9	97	B10	79	D3	55	E7	61
A10	71	B11	26	D4	56	E8	13
A11	72	B12	27	D5	57	E9	40
A12	98	B13	54	D6	33	E10	41
A13	73	B14	80	D7	9	E11	62
A14	51	C2	3	D8	34	E12	99
A15	74	C3	81	D9	58	E13	100
A16	75	C4	28	D10	35	E15	63
A17	21	C7	29	D11	36	E17	14
A18	76	C8	82	D12	85	E18	88
A19	77	C9	83	D14	37	E19	89
B2	22	C10	4	D15	38	E21	101
B3	2	C11	30	D16	59	F1	42
B4	52	C12	5	D18	10	F2	43

<u>PARTICLE</u>	<u>PAGE</u>	<u>PARTICLE</u>	<u>PAGE</u>	<u>PARTICLE</u>	<u>PAGE</u>	<u>PARTICLE</u>	<u>PAGE</u>
F5	44	F11	91	F19	105	F24	46
F7	90	F12	65	F20	17	F25	93
F8	15	F14	102	F22	45	F26	47
F9	64	F15	103	F23	92	F27	18
F10	16	F16	104				

COSMIC DUST

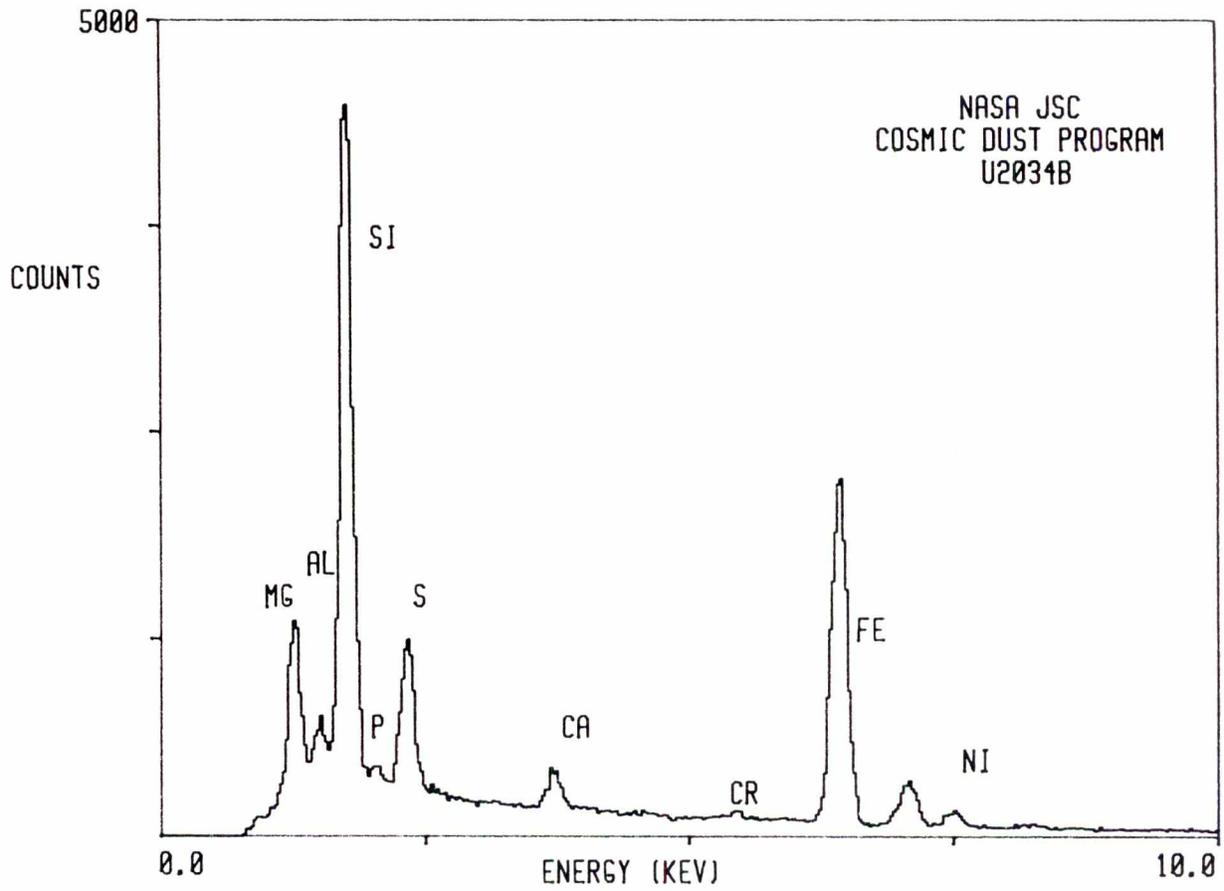
U2034 B 3



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COMMENTS:

UB3

S-87-45946



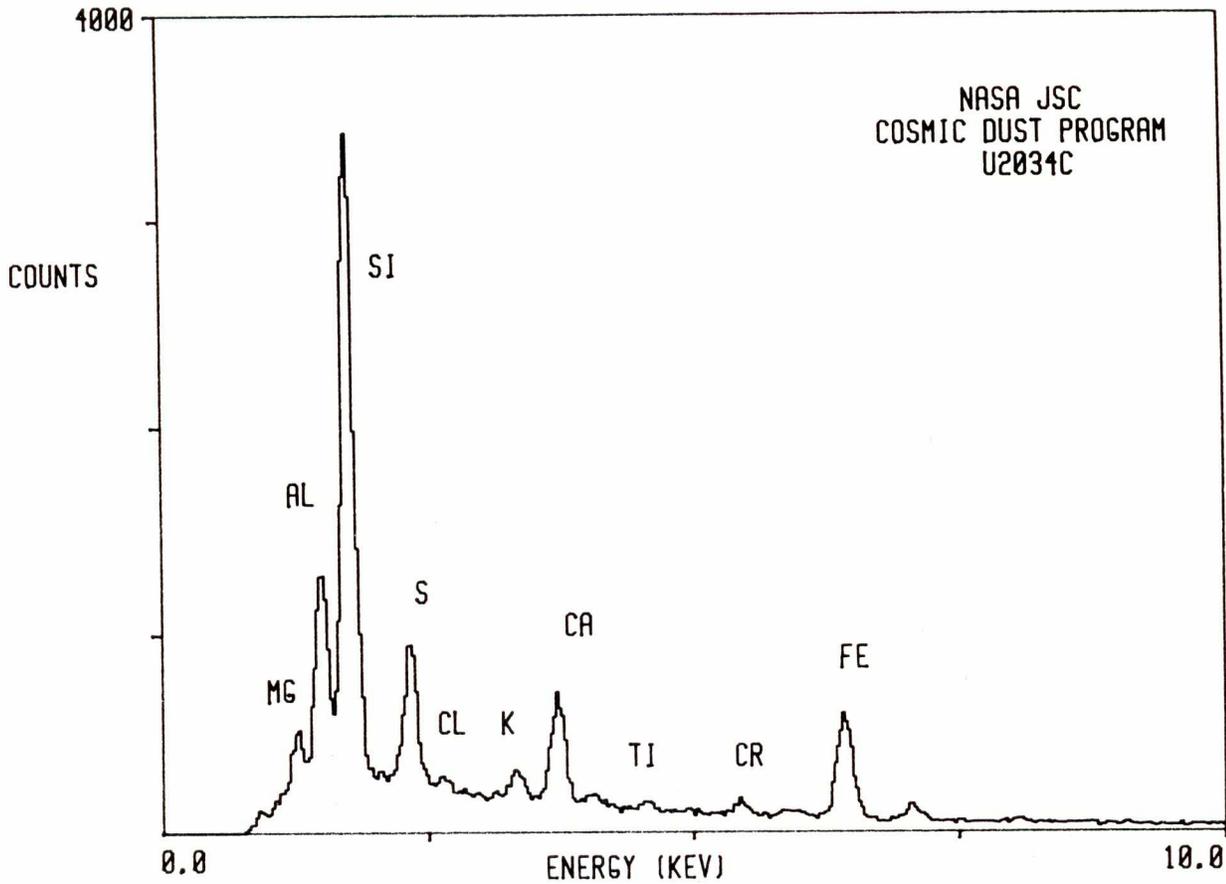
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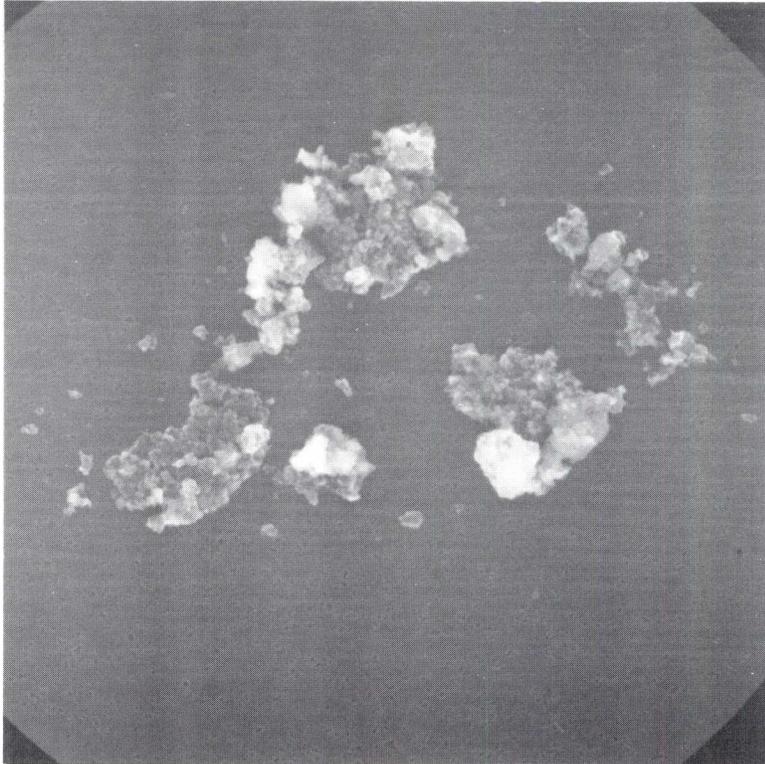
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COMMENTS:

UC2

S-87-45962



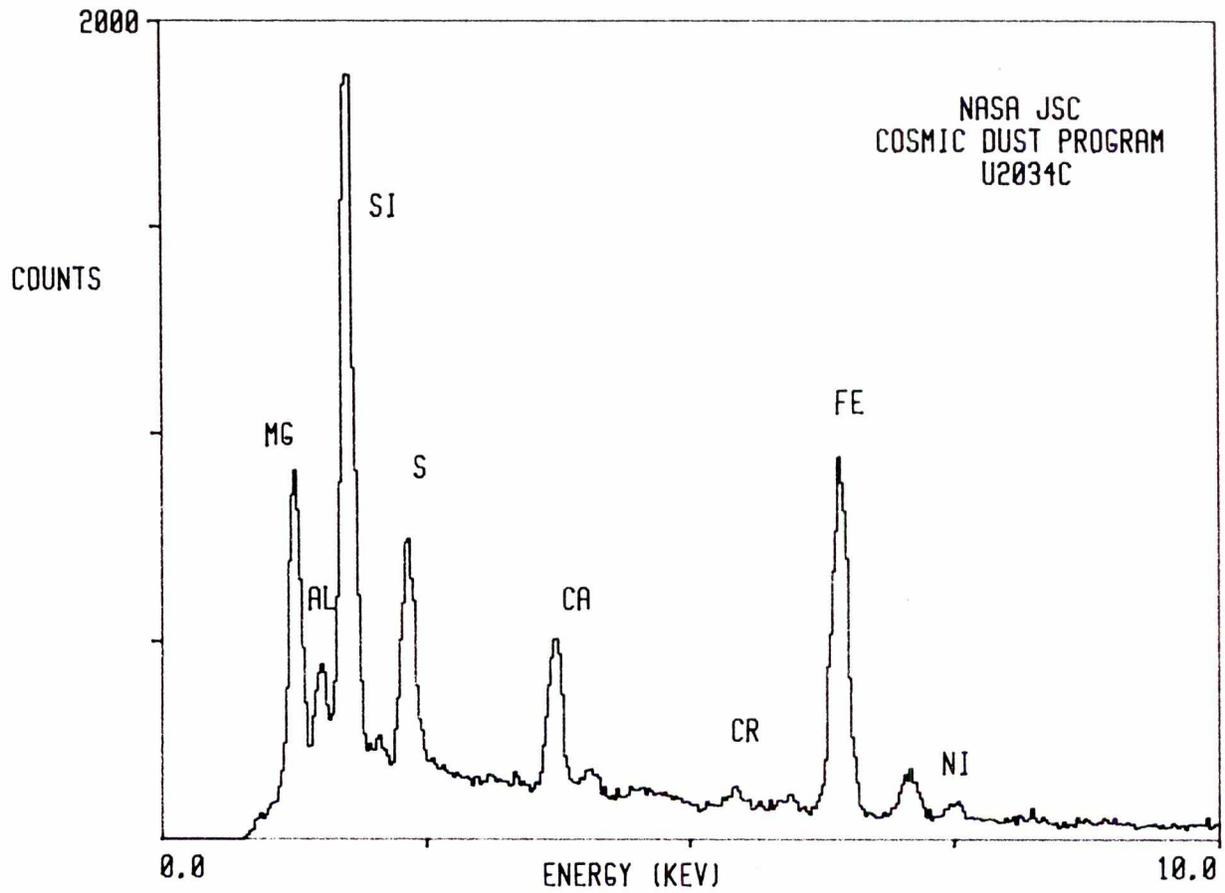
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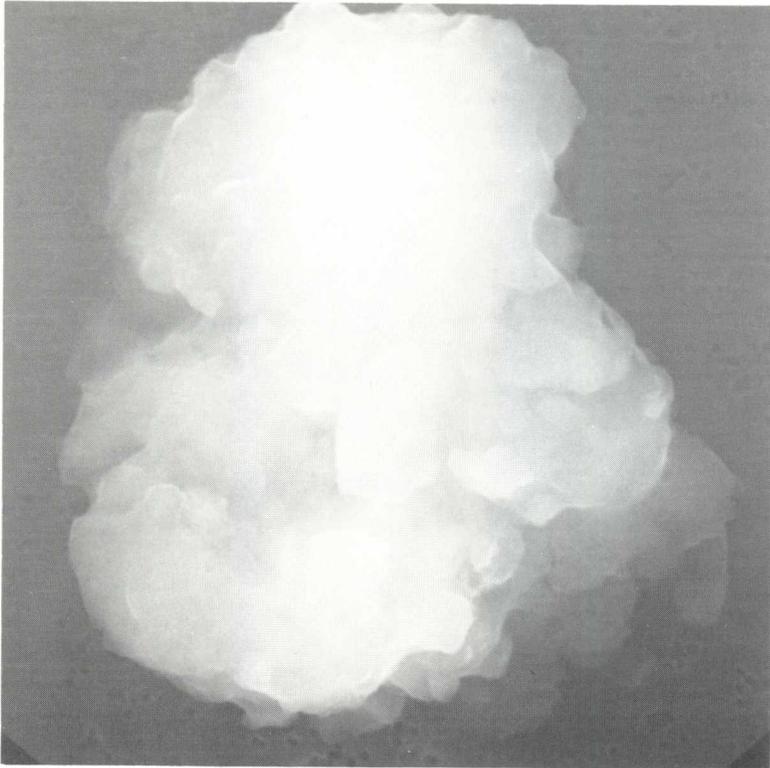
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Field of particles

UC10B

S-87-45969



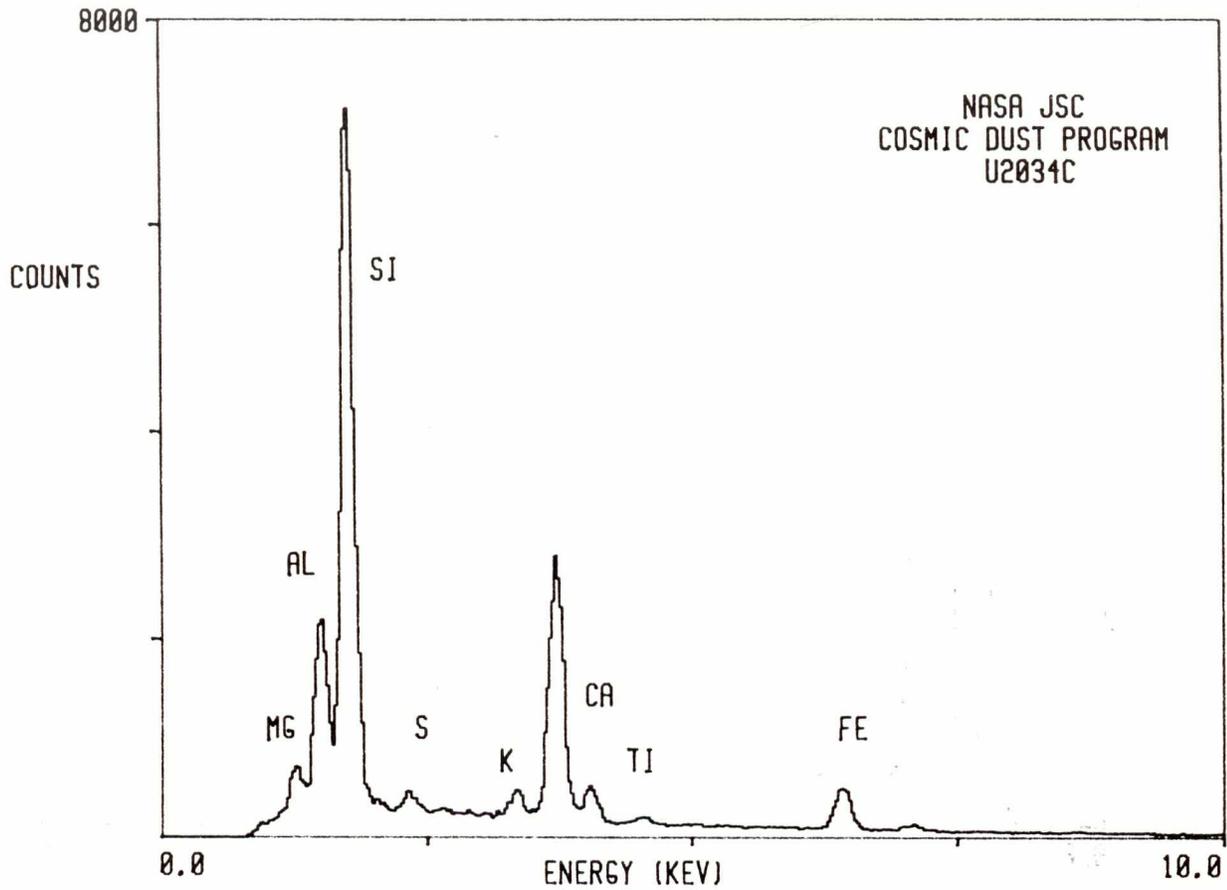
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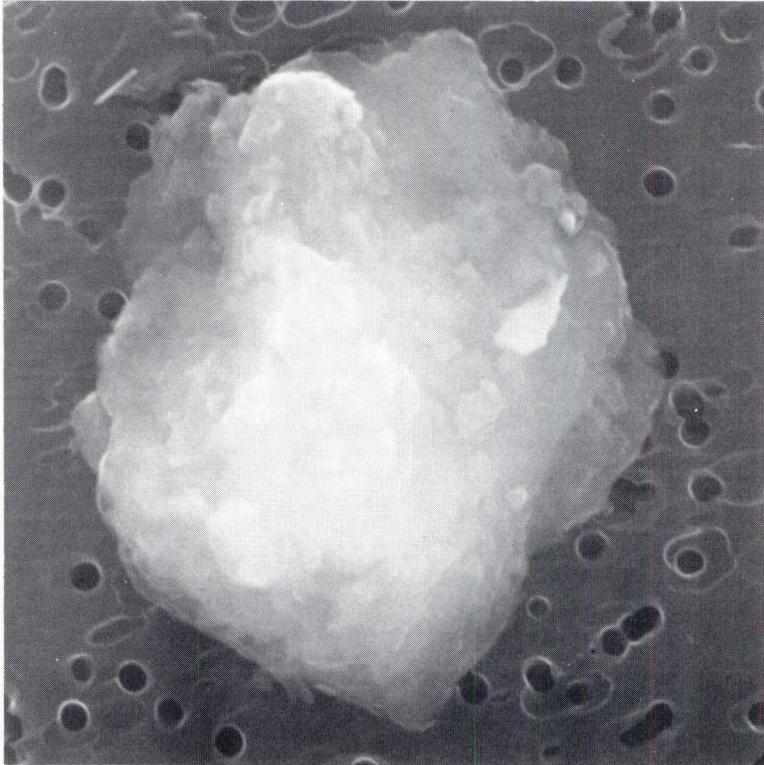
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LUSTER: D/SV
TYPE: C
COMMENTS:

UC12

S-87-45972



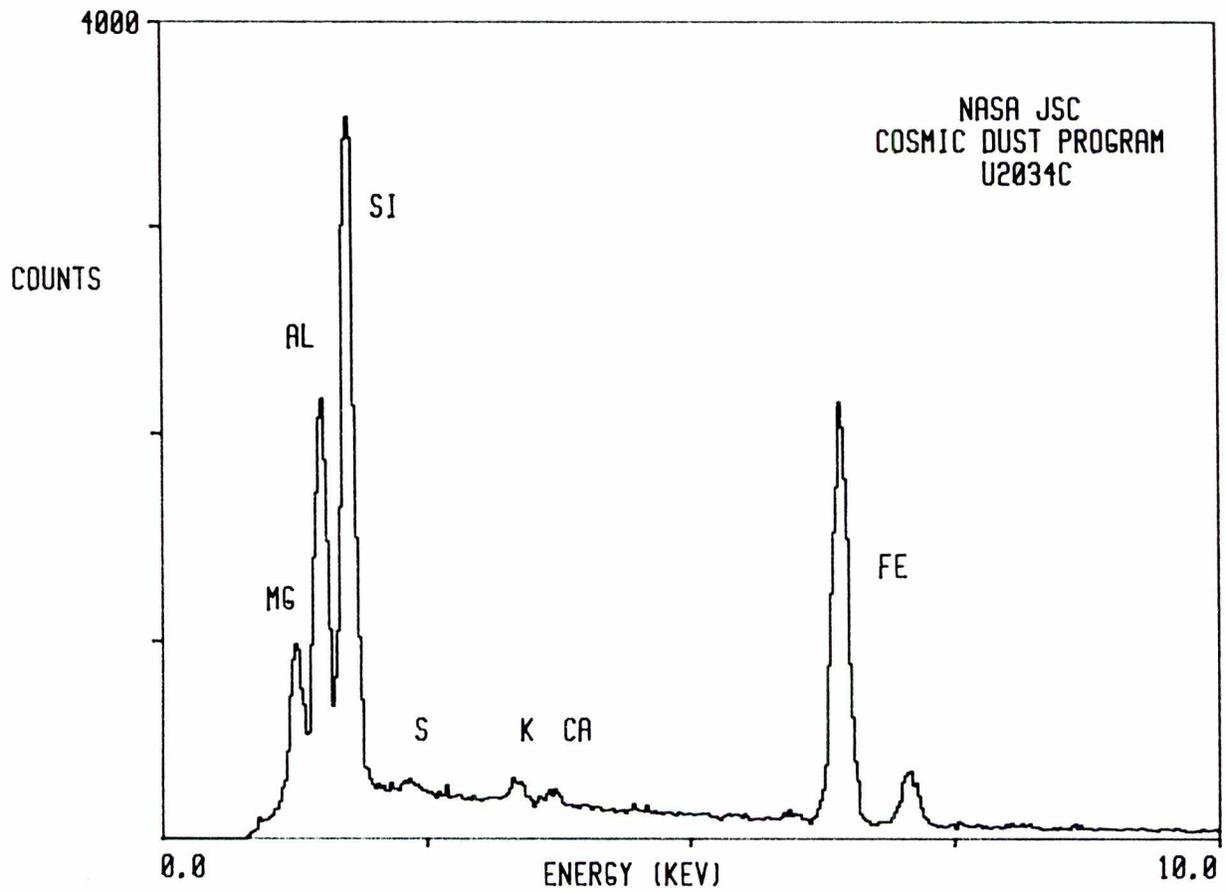
U2034 C 17



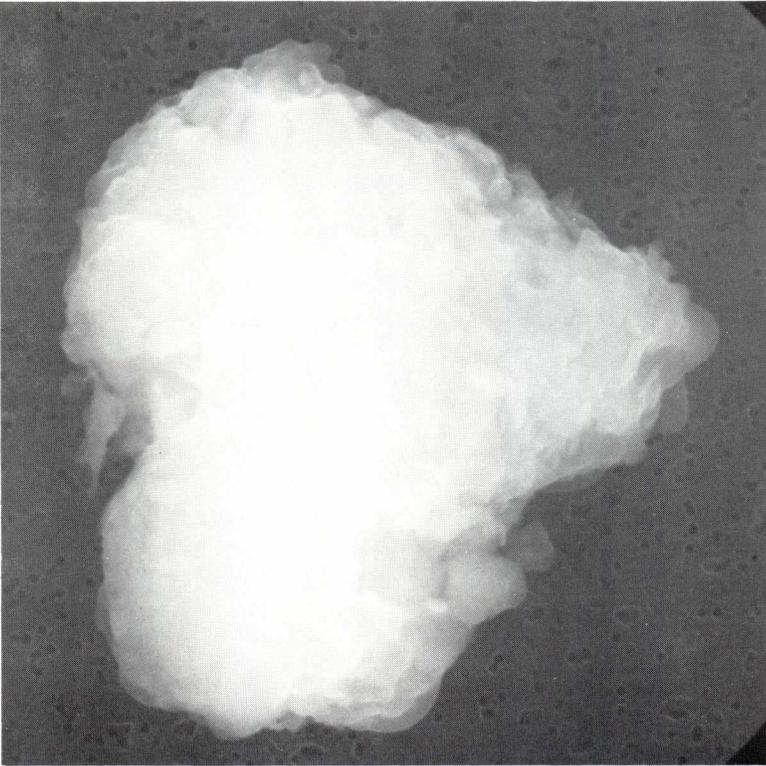
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COMMENTS:

UC17

S-87-45975

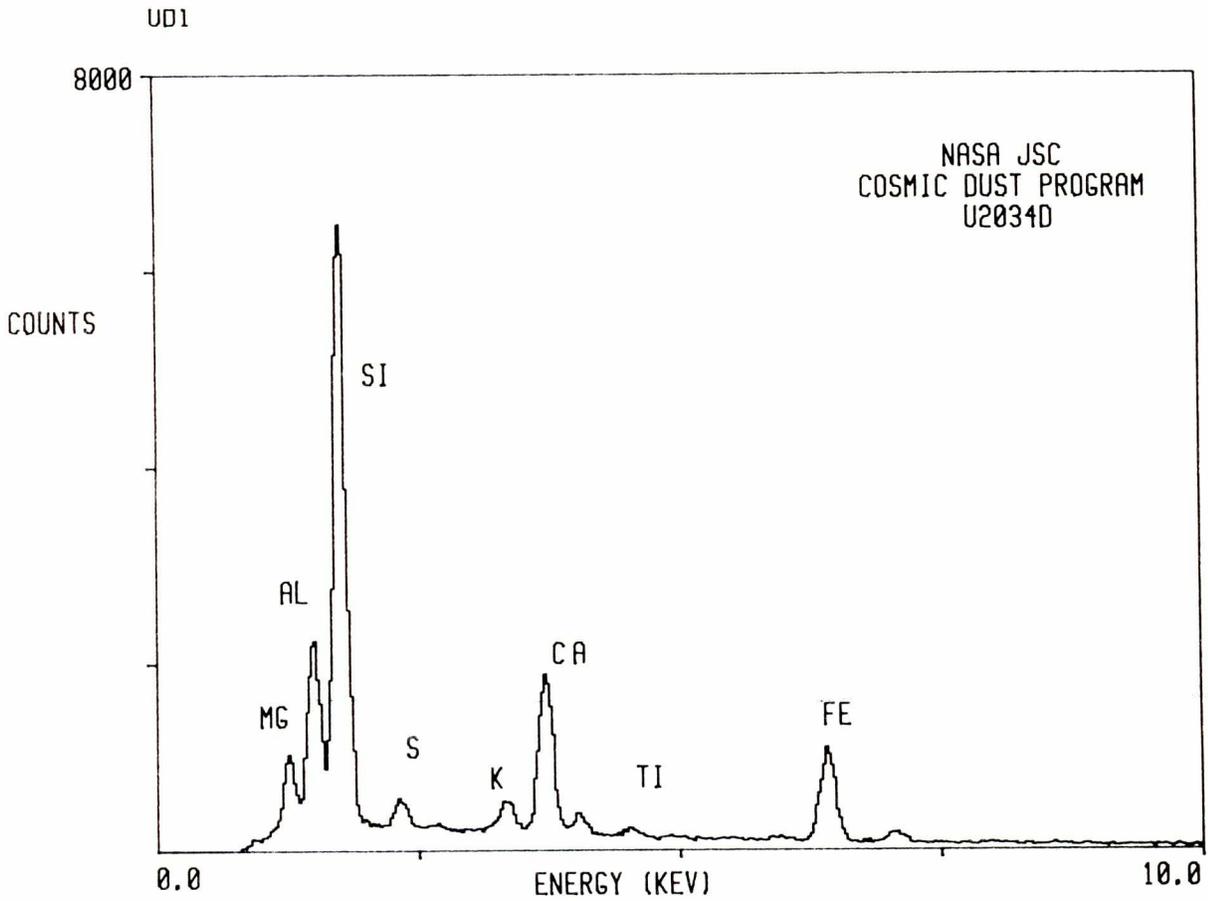


U2034 D 1

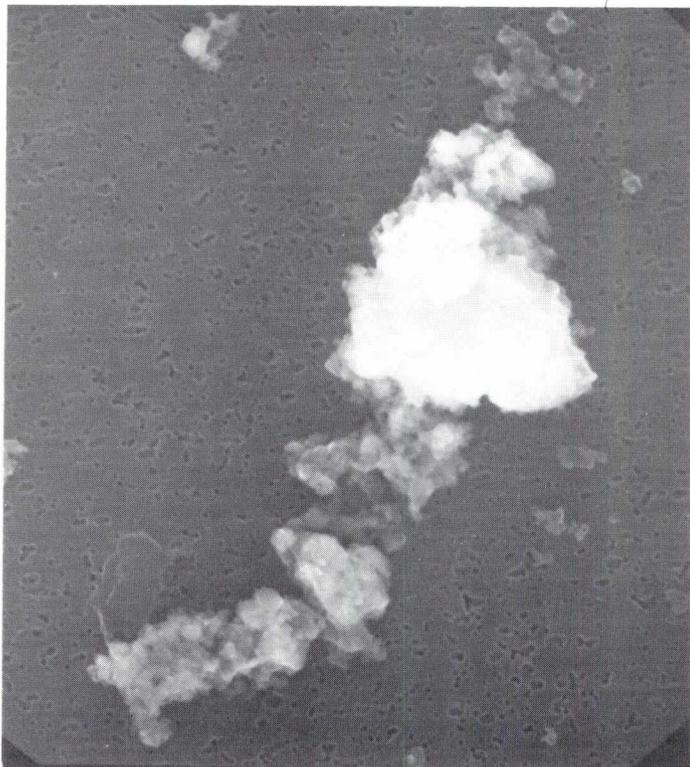


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COMMENTS:

S-87-45979



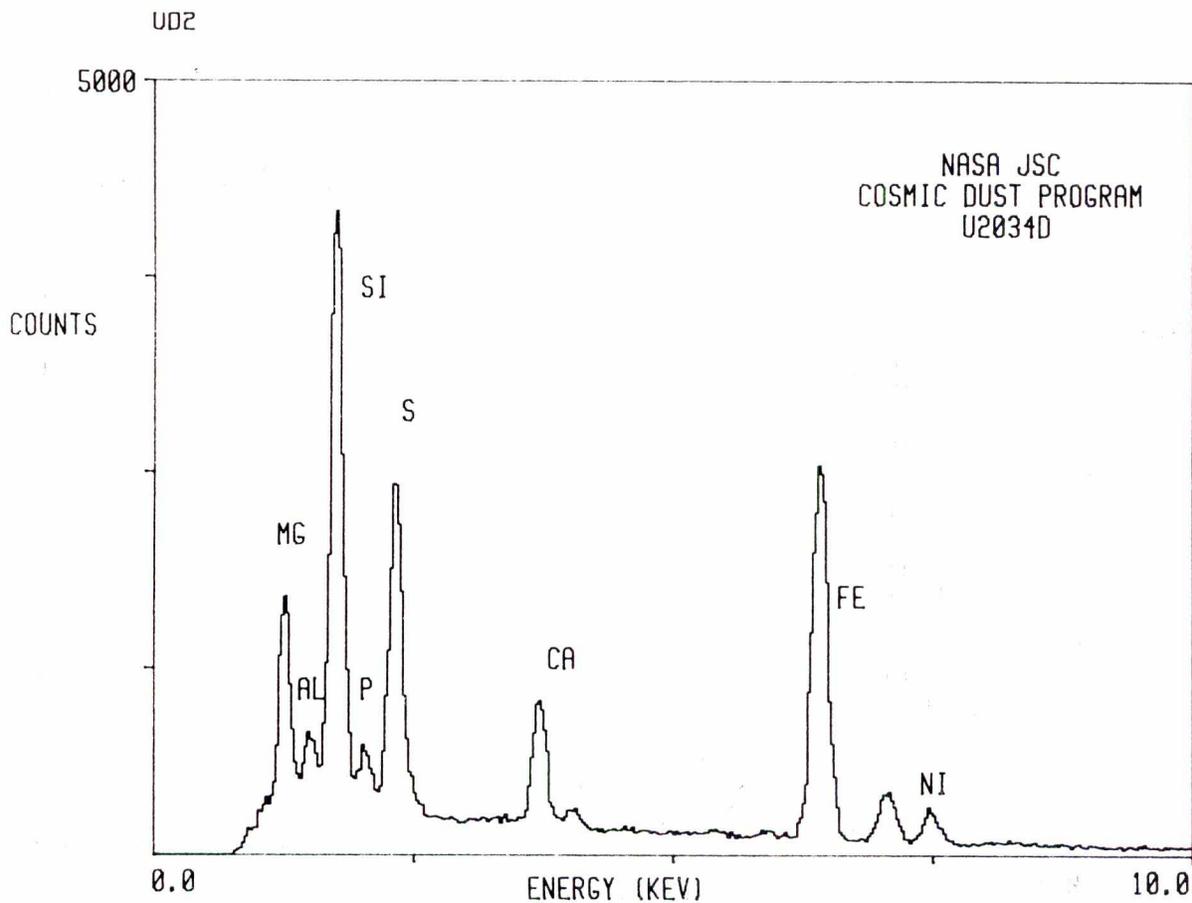
U2034 D 2



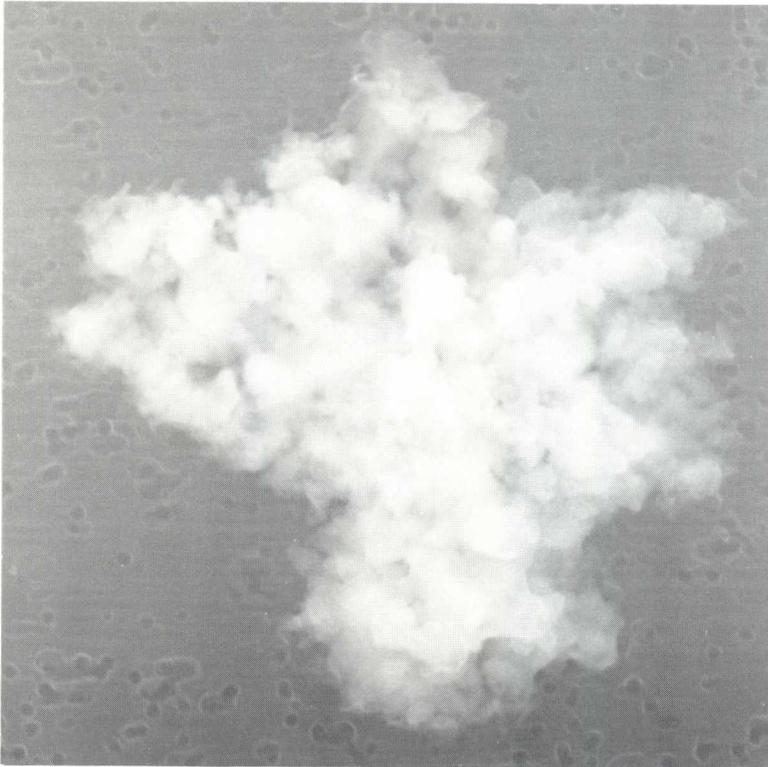
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COLOR: Black
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TYPE: C

COMMENTS:
Size of largest
particle in a
field of particles

S-87-45981

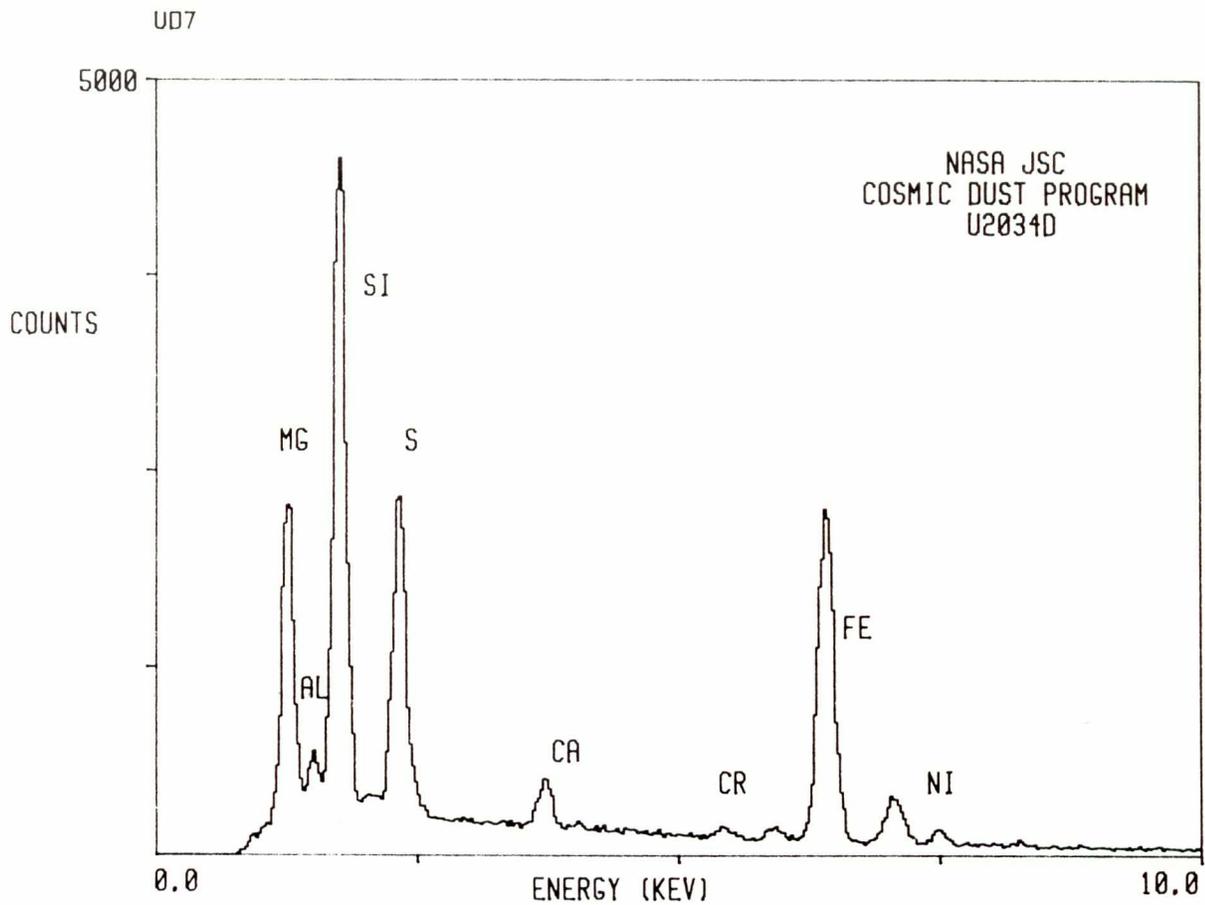


U2034 D 7

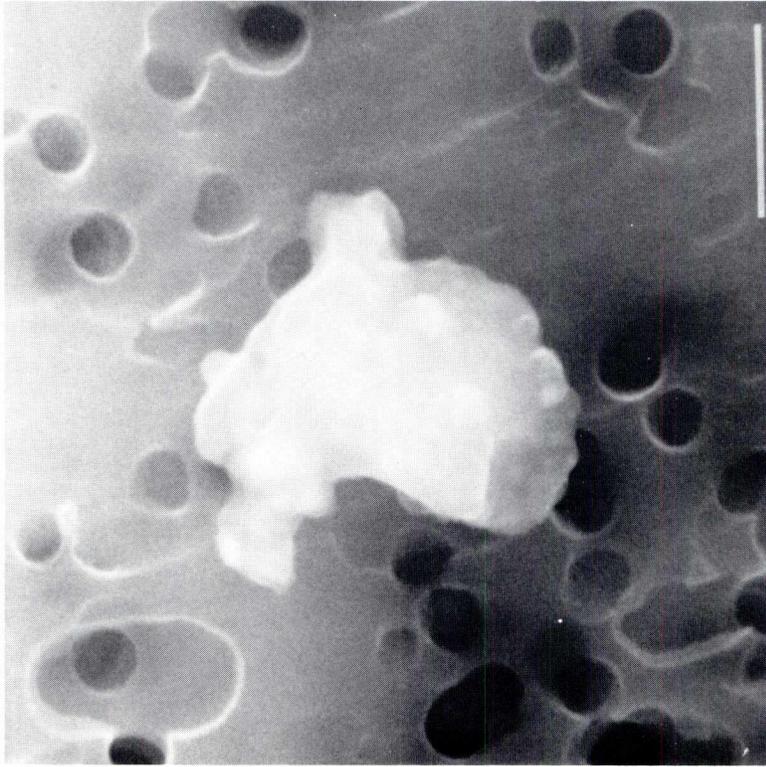


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COMMENTS:

S-87-45985



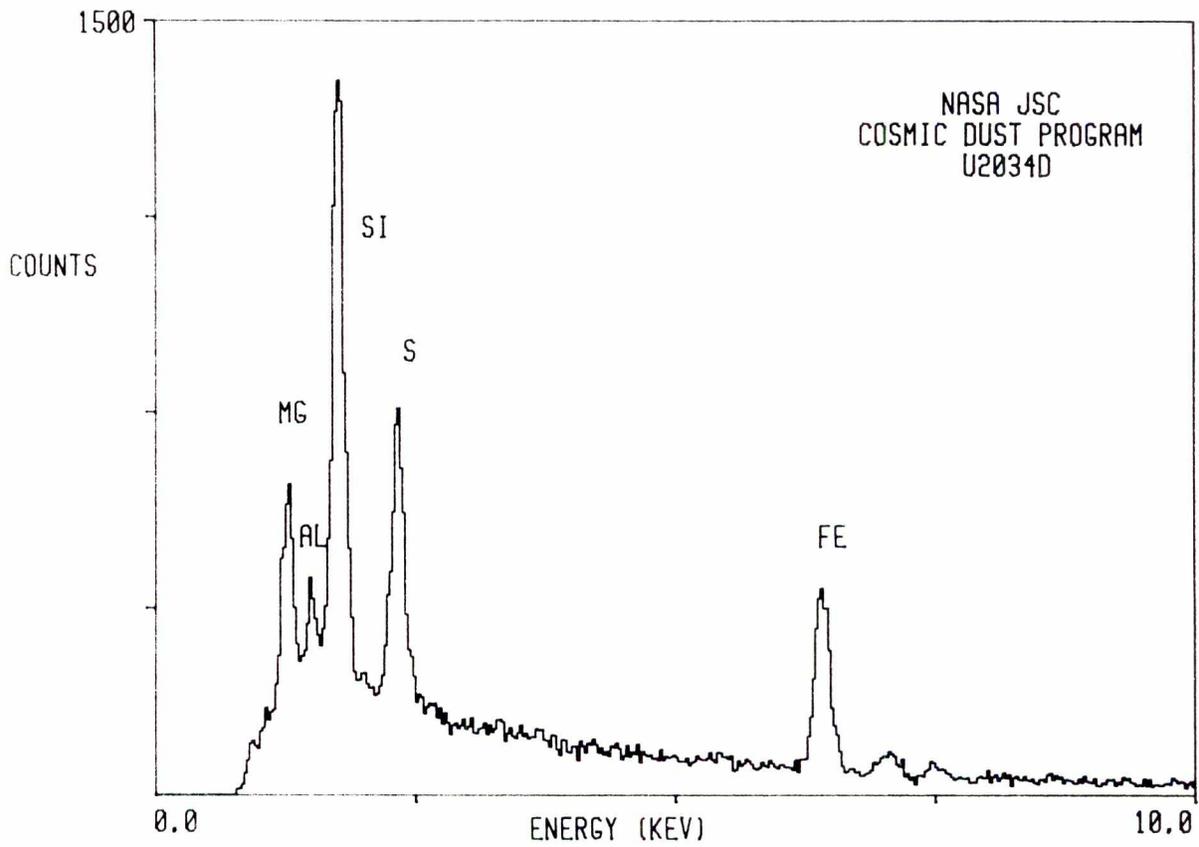
U2034 D 18



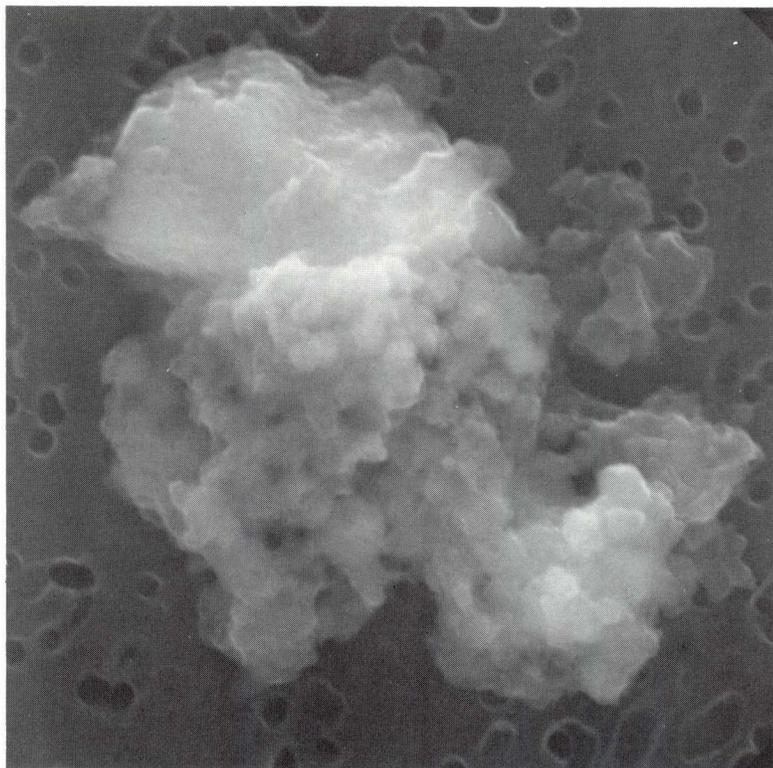
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COMMENTS:

S-87-45995

UD18



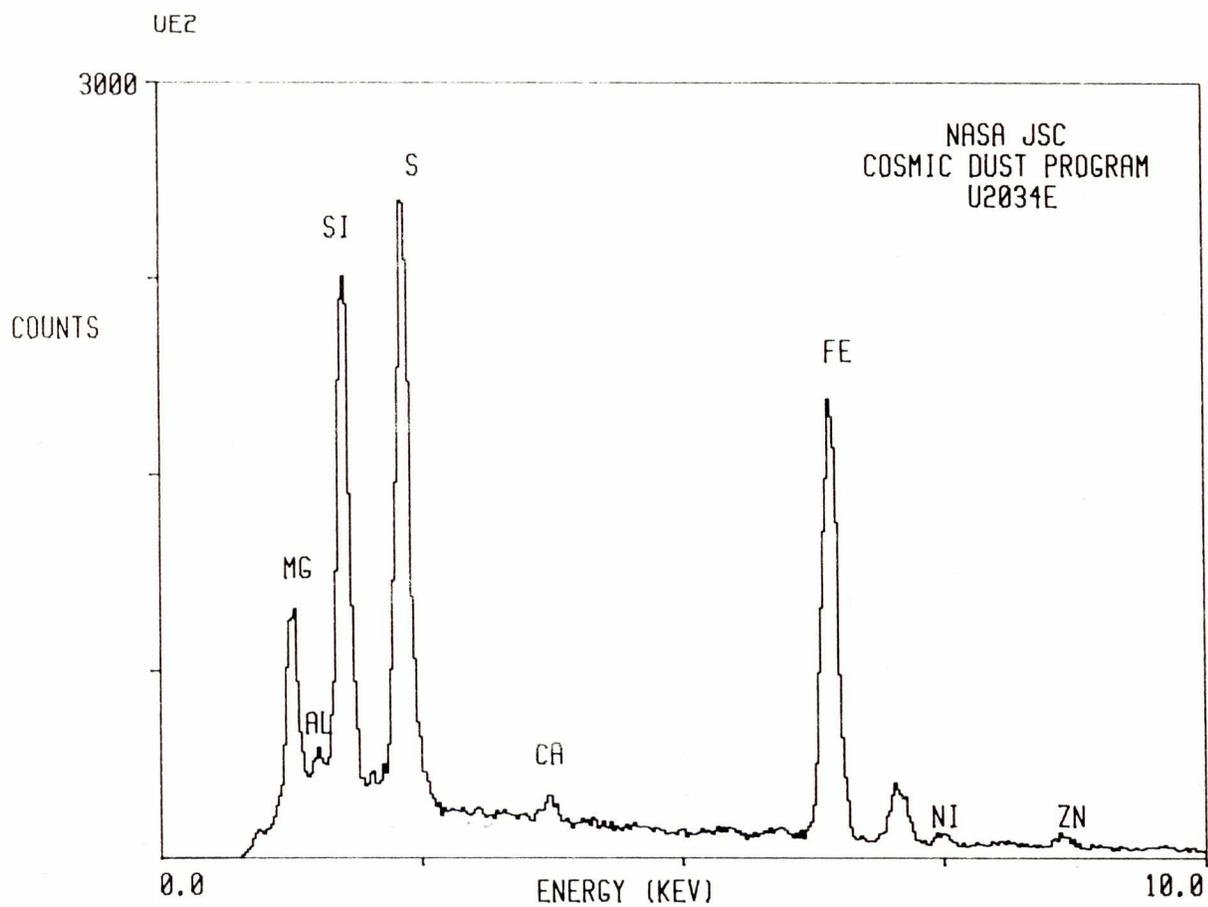
U2034 E 2



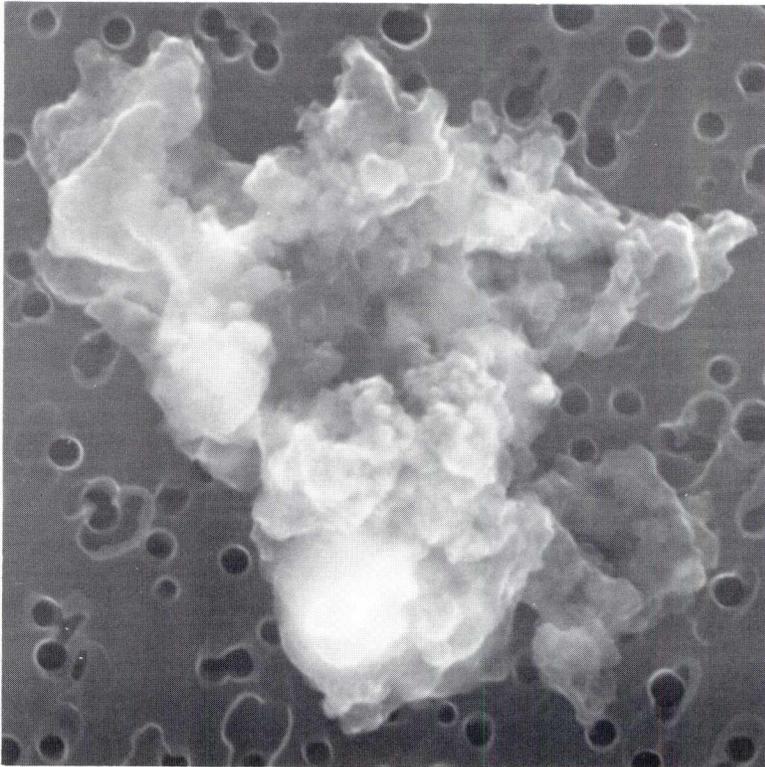
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TYPE: C

COMMENTS:
May be related to
U2034E3

S-87-45998



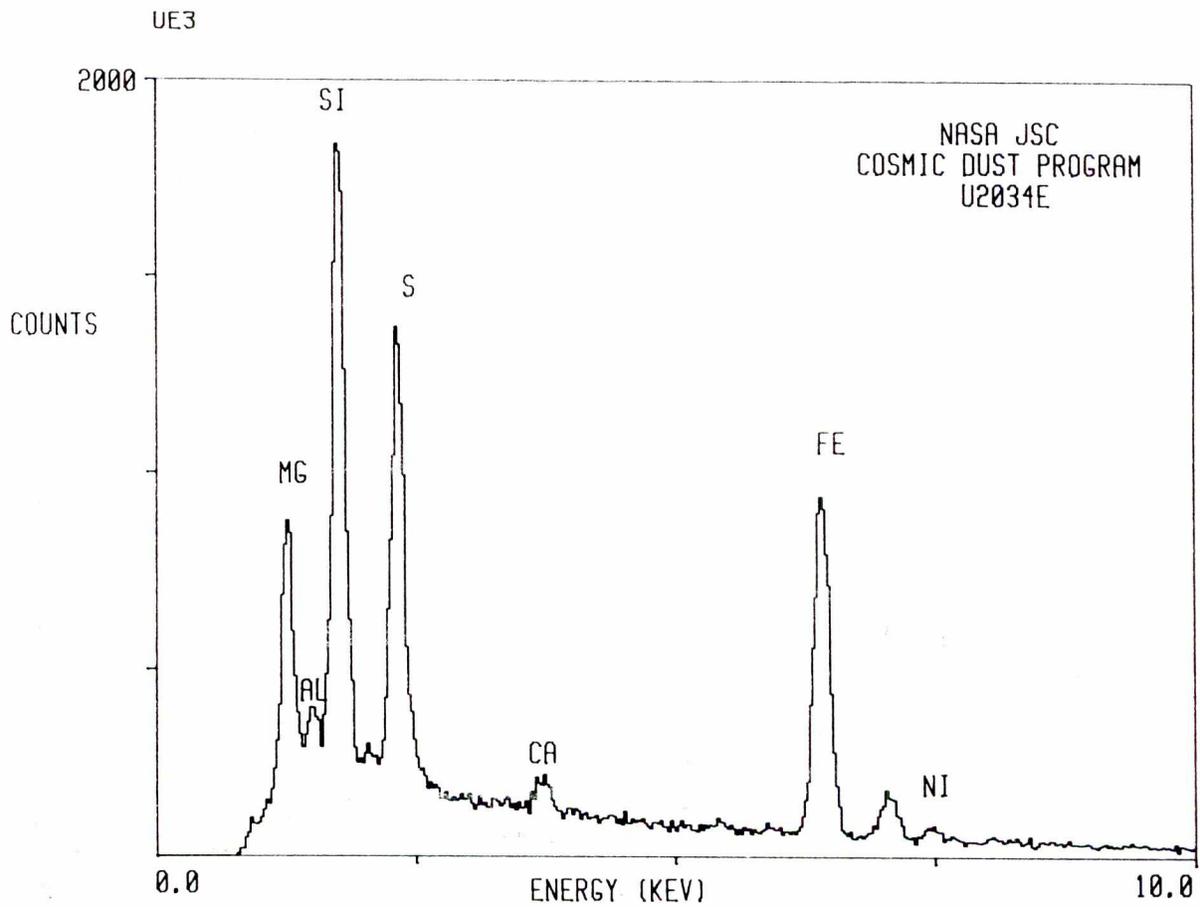
U2034 E 3



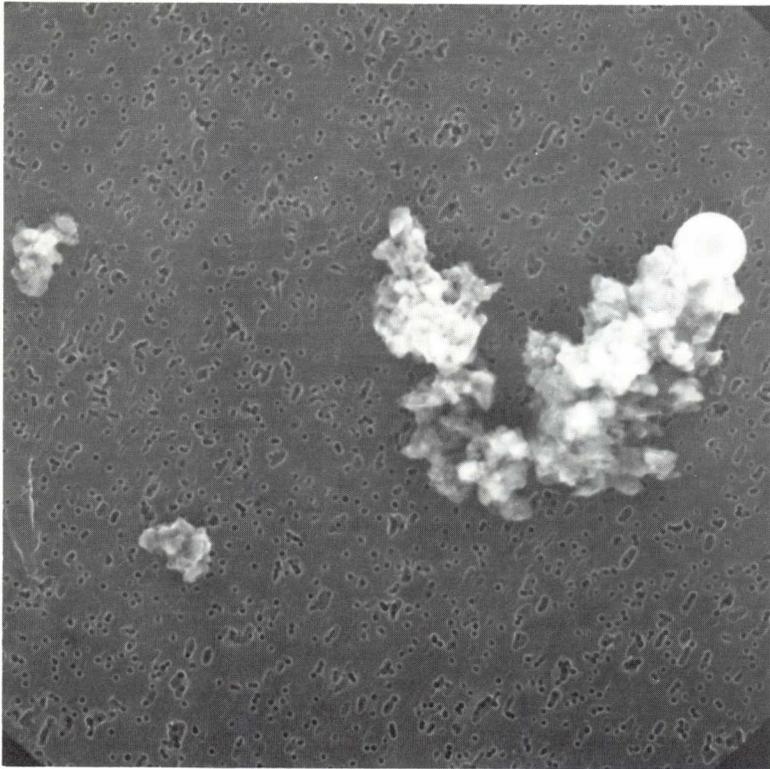
SIZE: 8
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: C

COMMENTS:
May be related to
U2034E2

S-87-45999

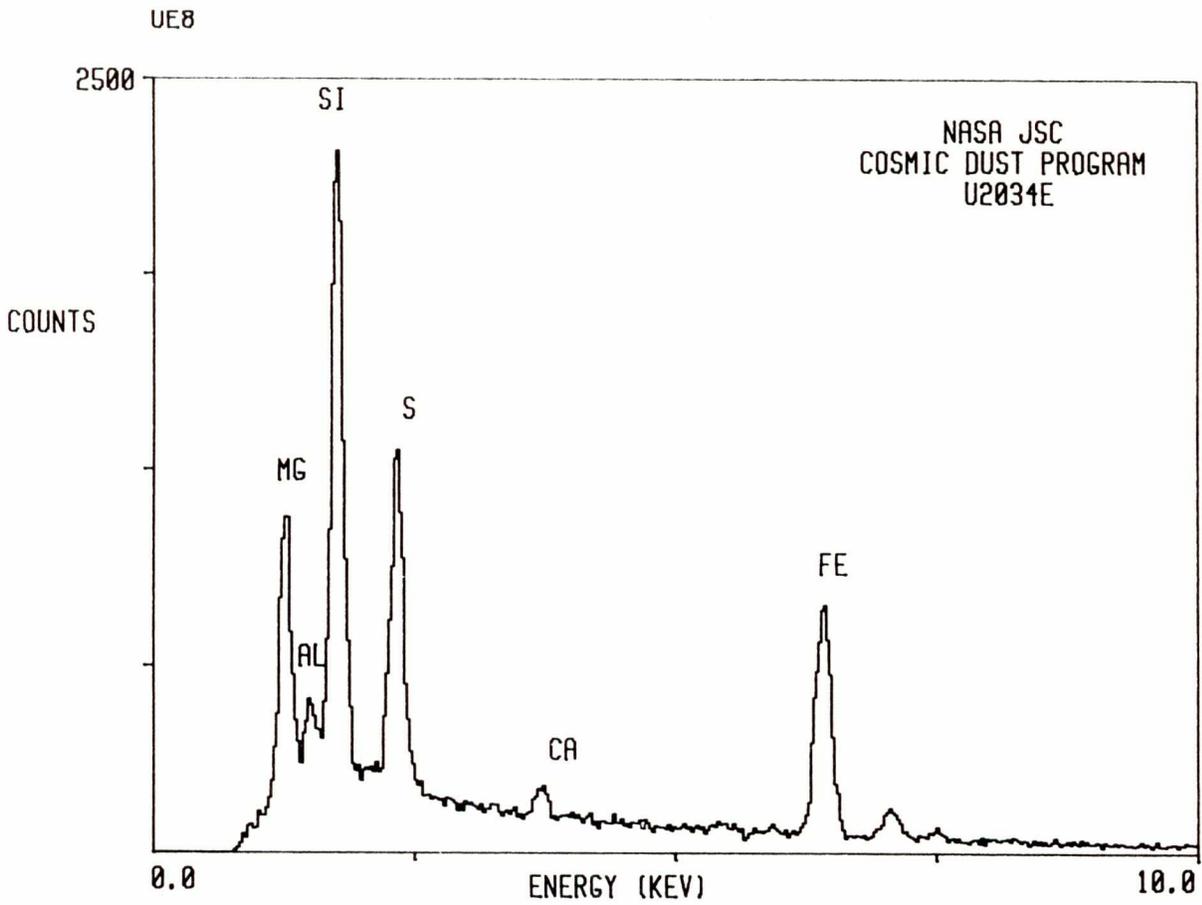


U2034 E 8

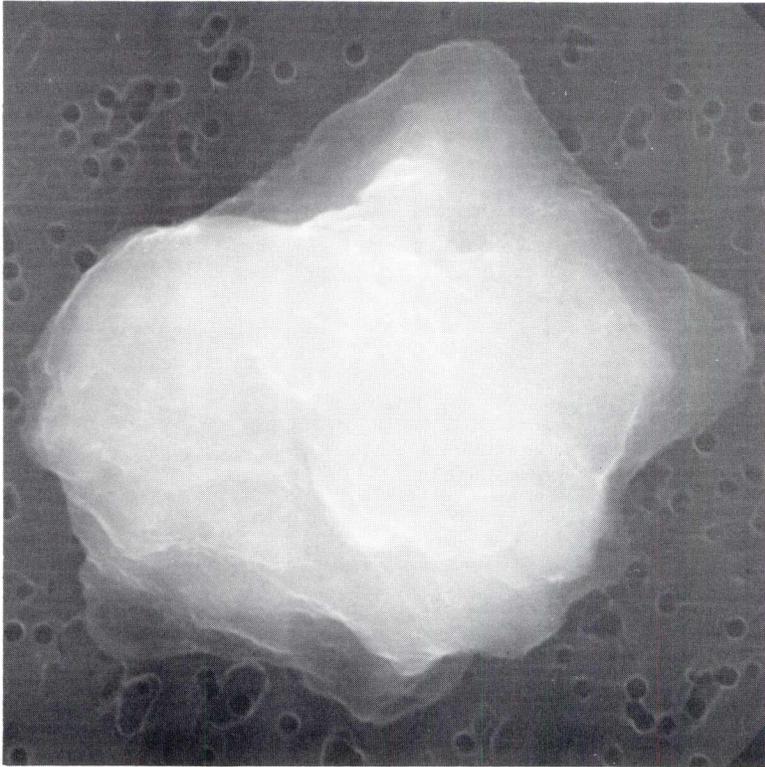


SIZE: 18x12
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: C
COMMENTS:

S-87-46004



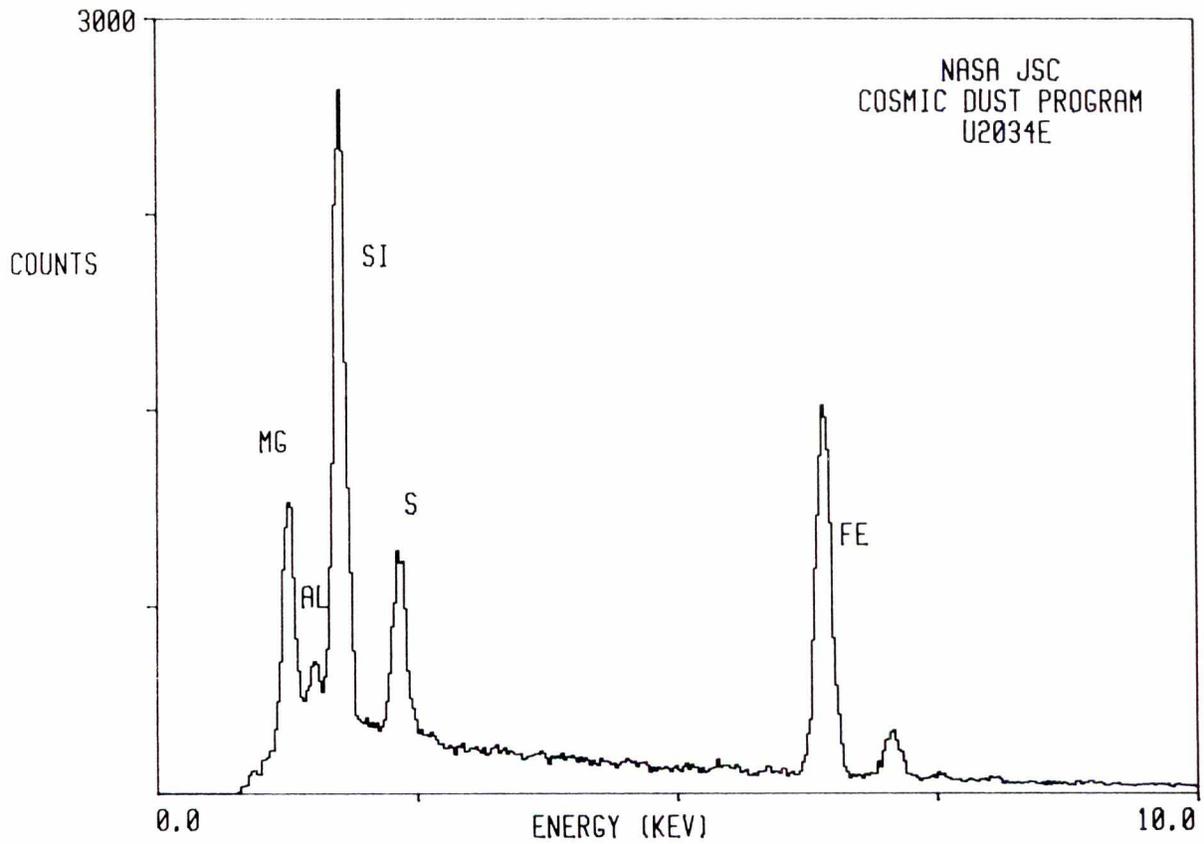
U2034 E 17



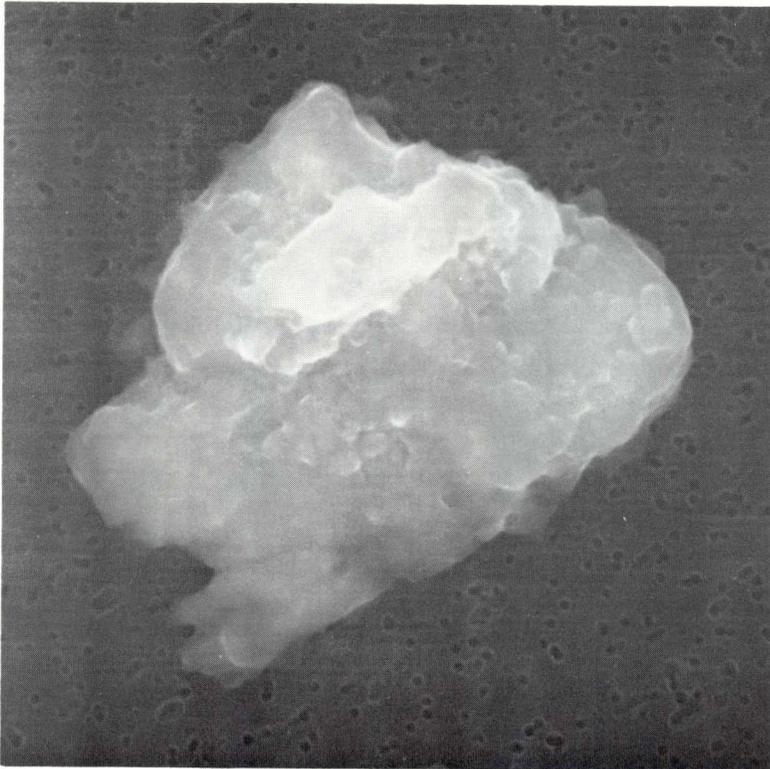
SIZE: 13x12
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: C
COMMENTS:

S-87-46011

UE17

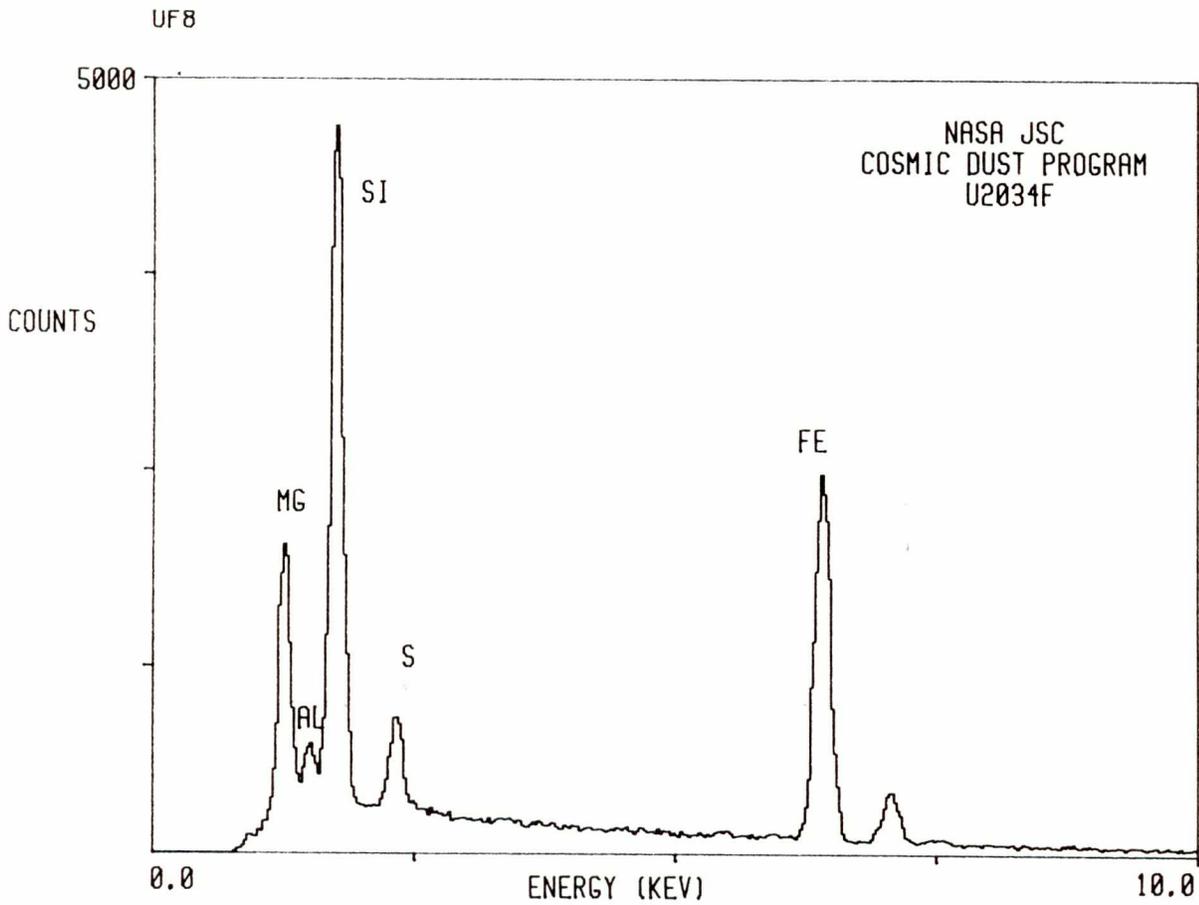


U2034 F 8

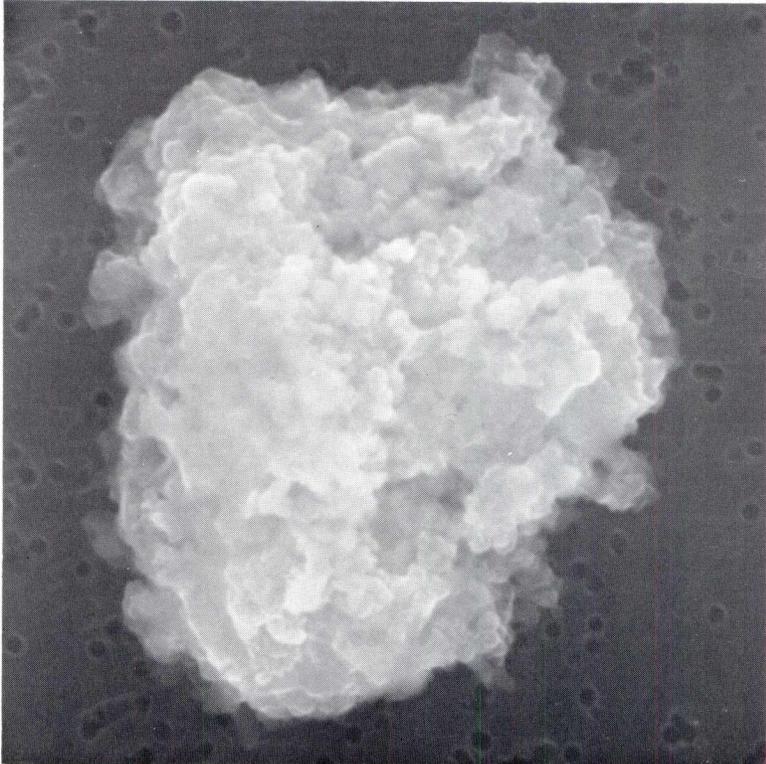


SIZE: 15x14
SHAPE: I
TRANS.: O/TL
COLOR: Black to brown
LUSTER: D
TYPE: C
COMMENTS:

S-87-46020

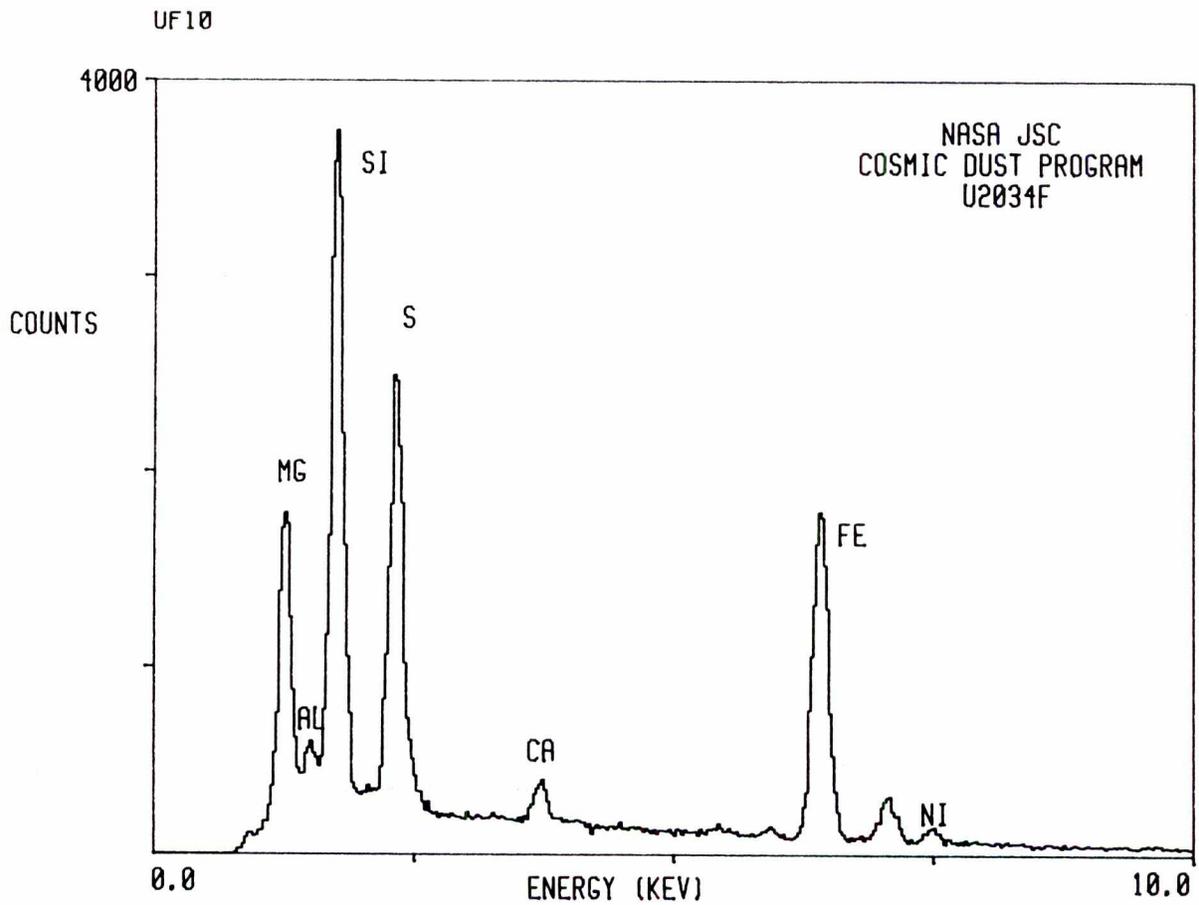


U2034 F 10

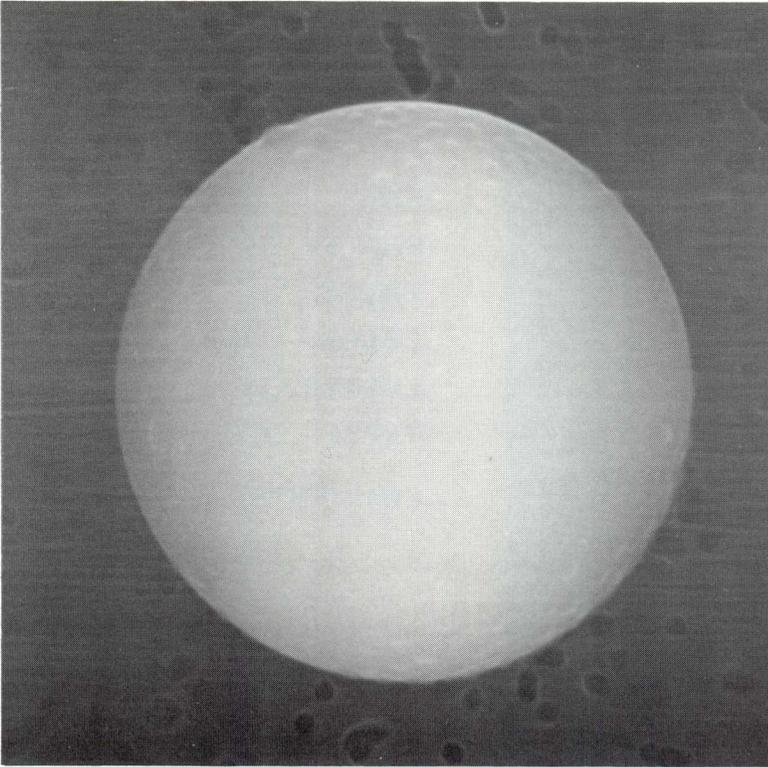


SIZE: 12
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: C
COMMENTS:

S-87-46022

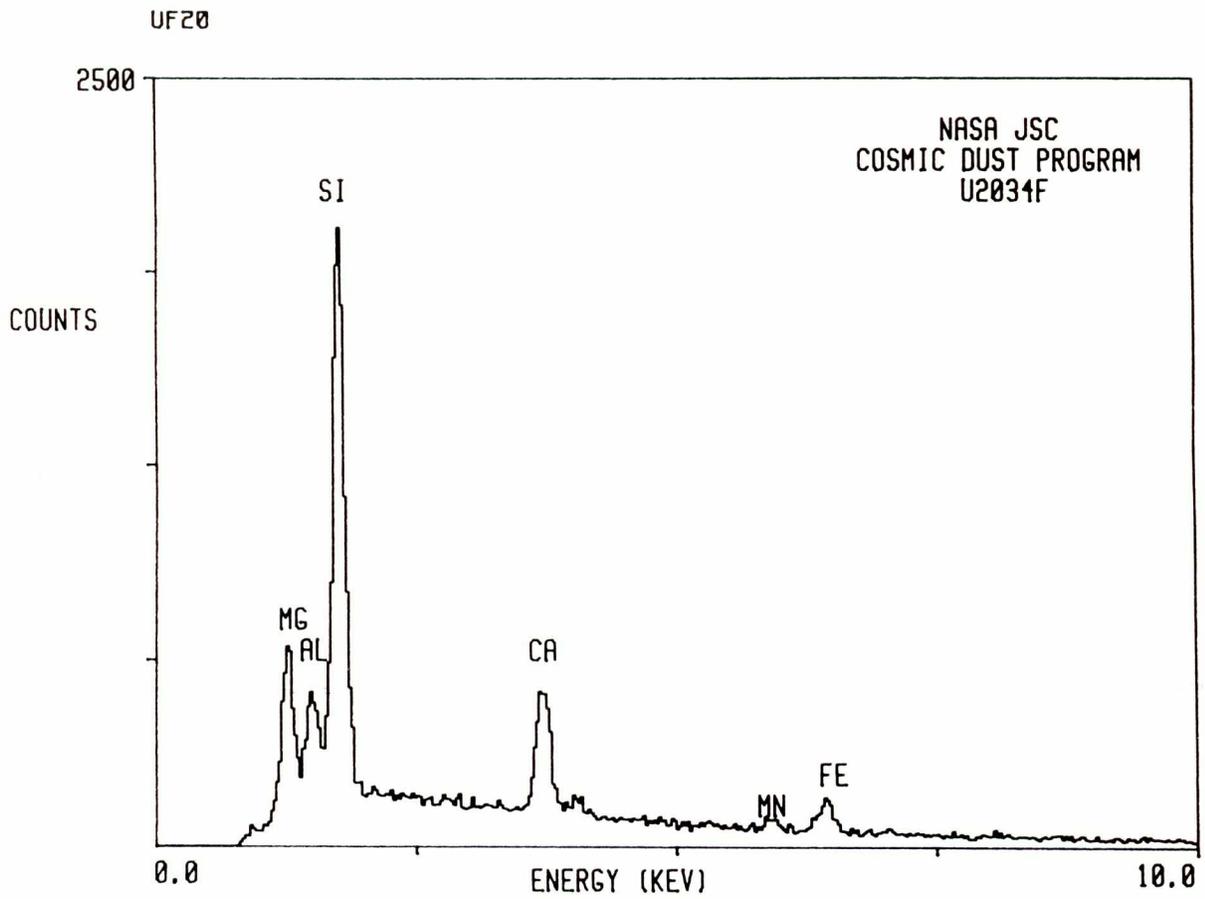


U2034 F 20

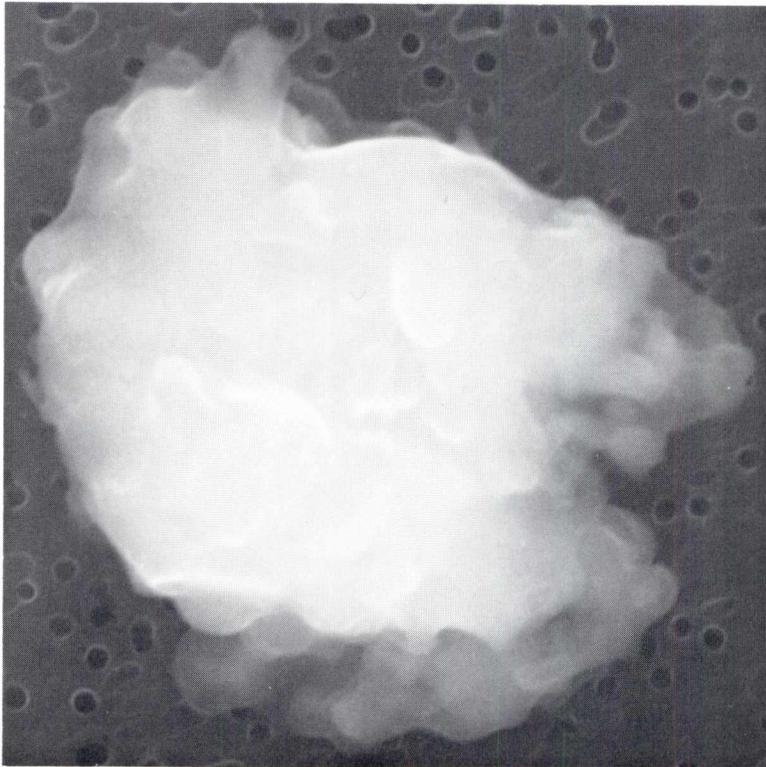


SIZE: 12
SHAPE: S
TRANS.: T
COLOR: Yellow
LUSTER: V
TYPE: C
COMMENTS:

S-87-46029

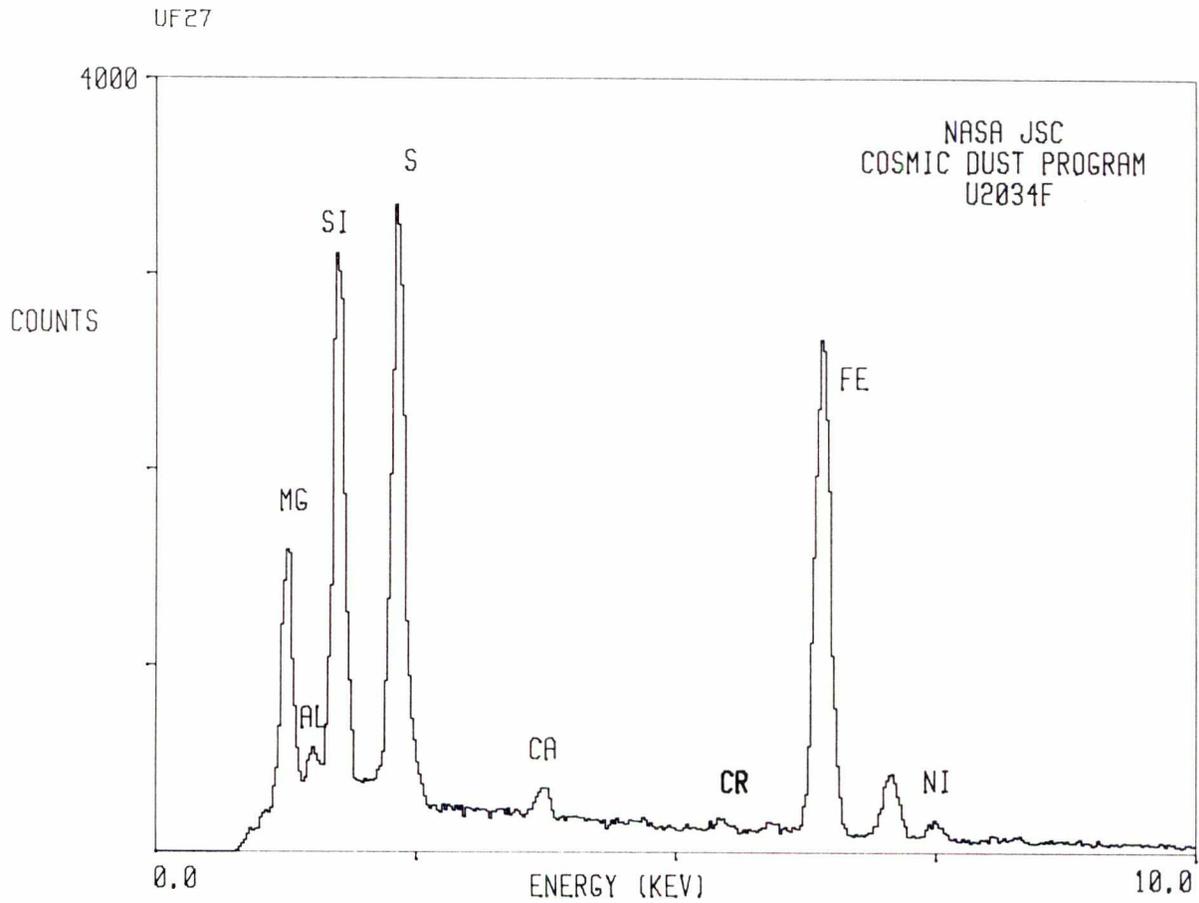


U2034 F 27



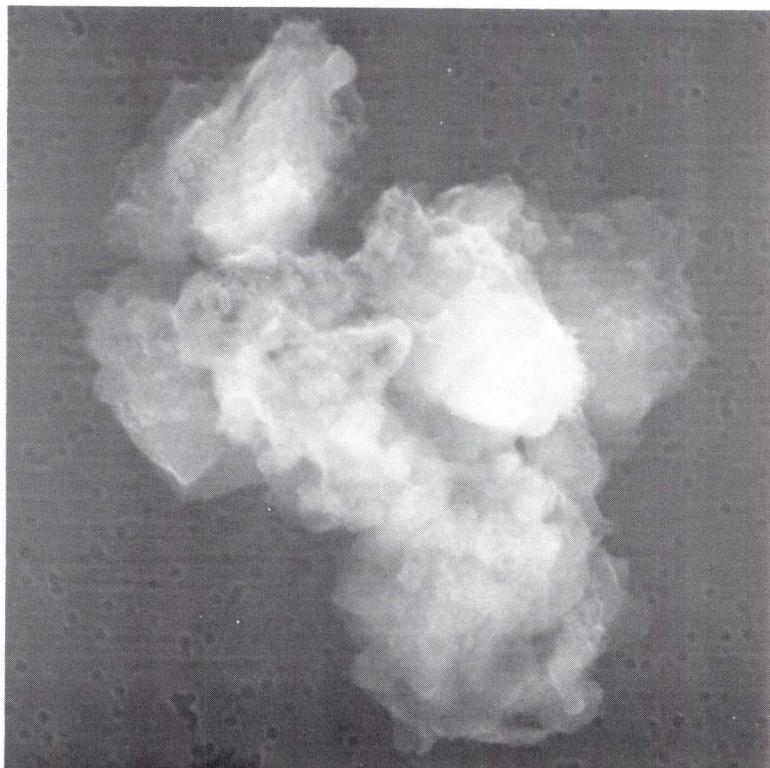
SIZE: 13x12
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: C
COMMENTS:

S-87-46035



UNCERTAIN

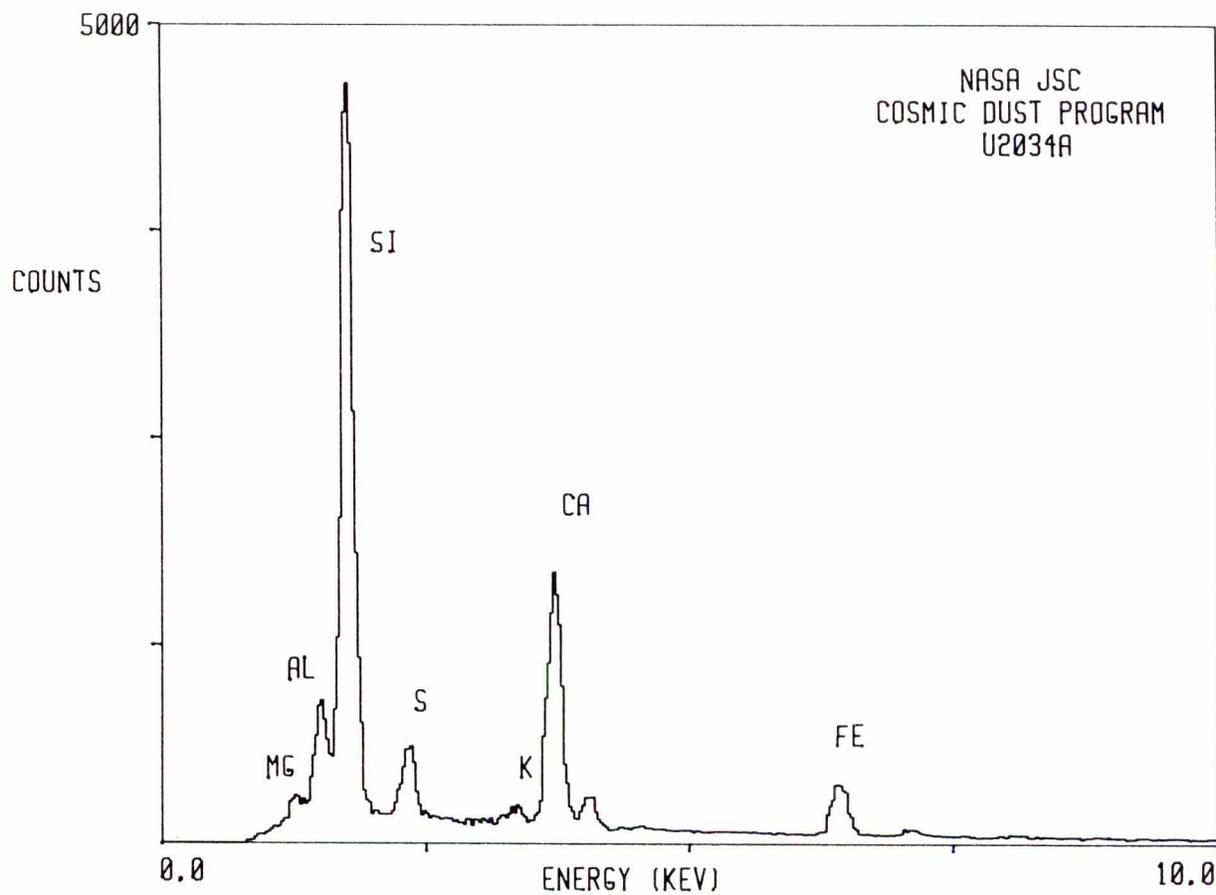
U2034 A 4



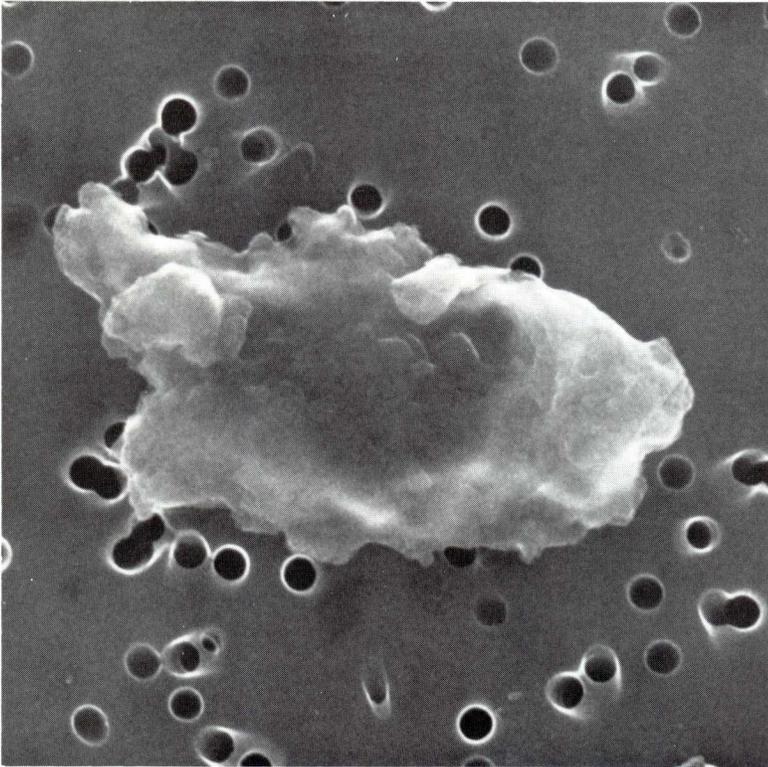
SIZE: 20x18
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: ?
COMMENTS:

UA1

S-87-45925



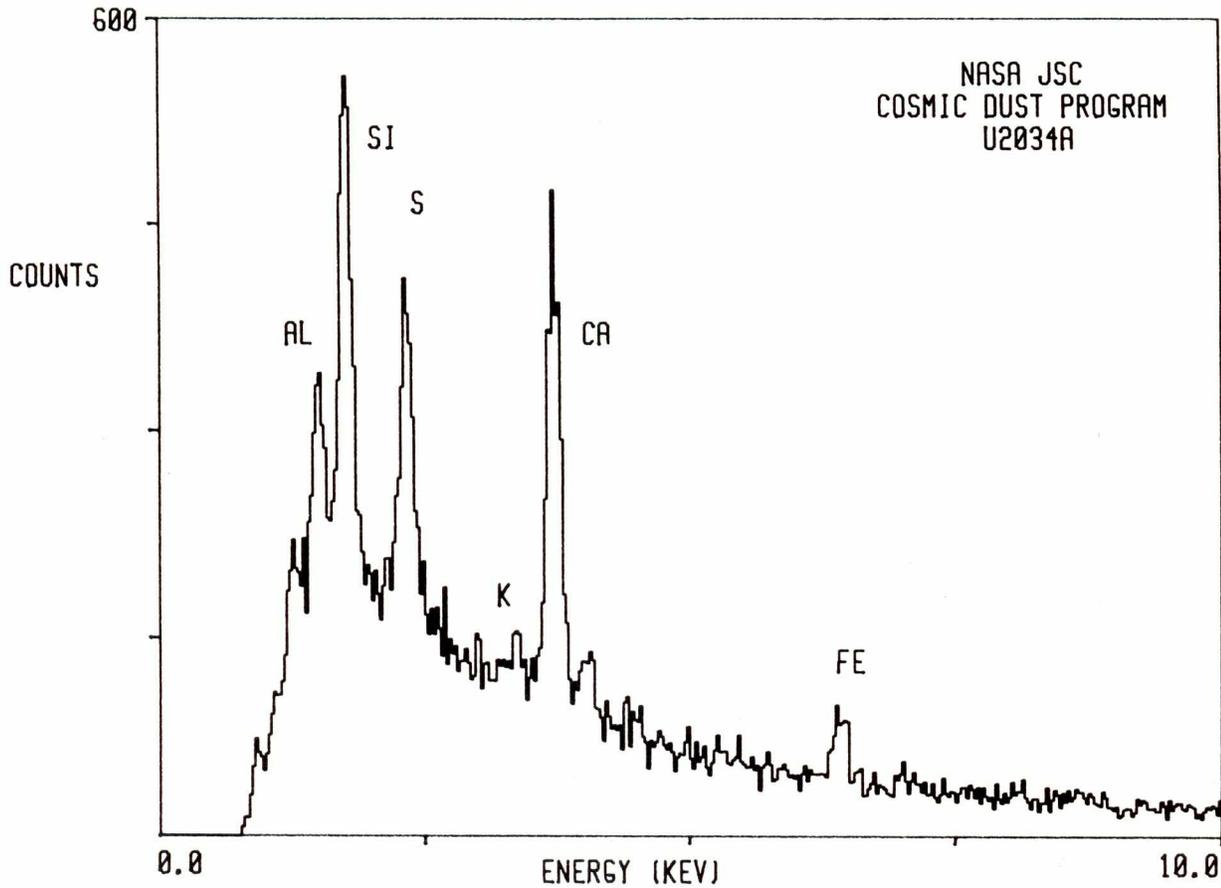
U2034 A 17



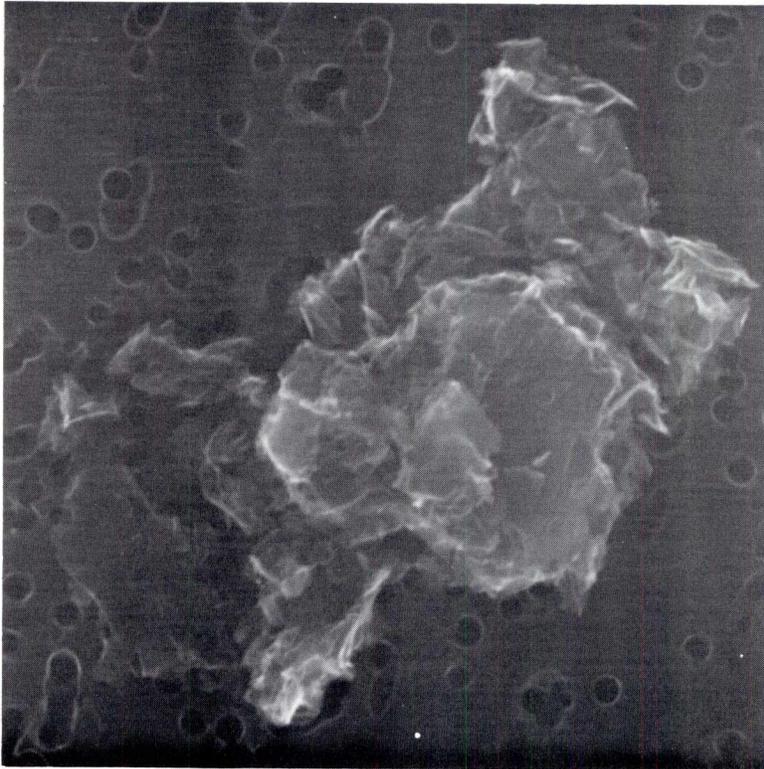
SIZE: 5x4
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?
COMMENTS:

UA17

S-87-45938



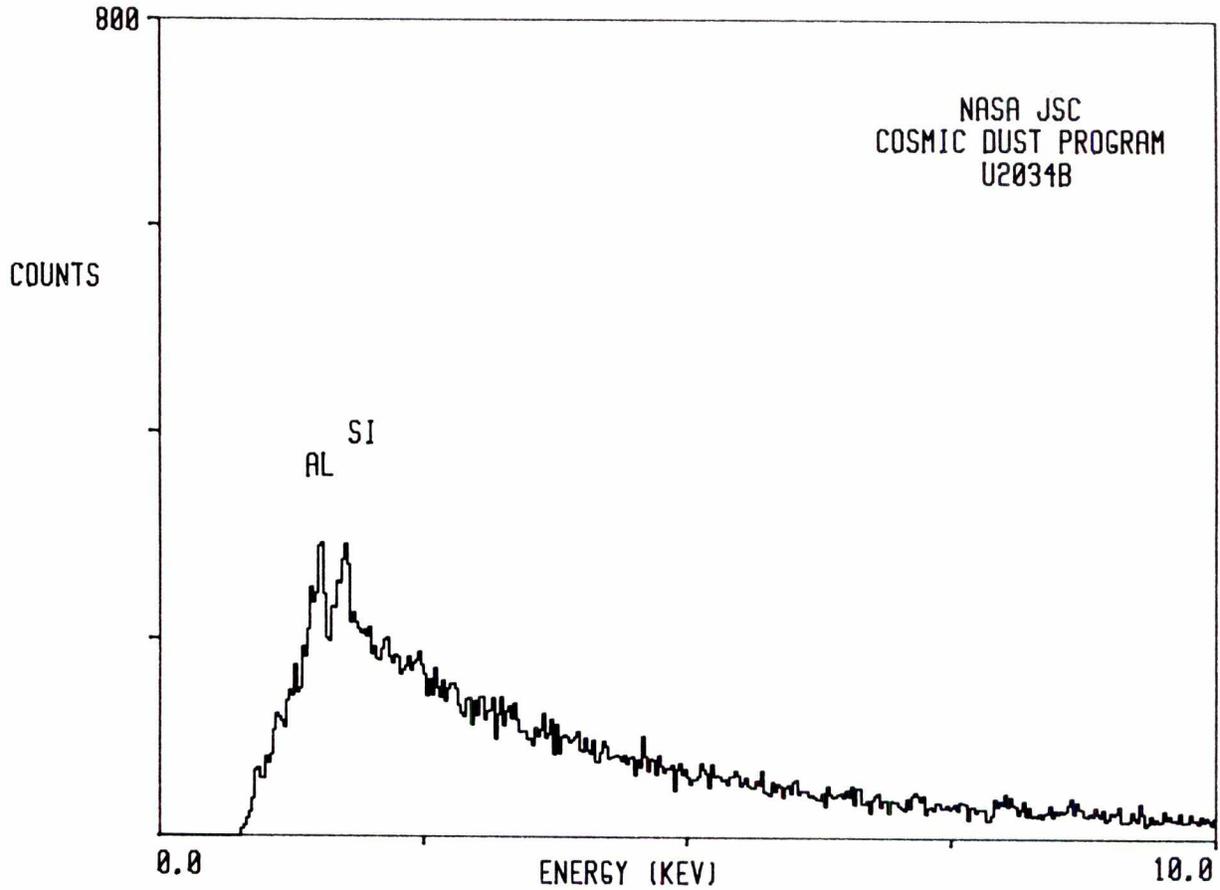
U2034 B 2



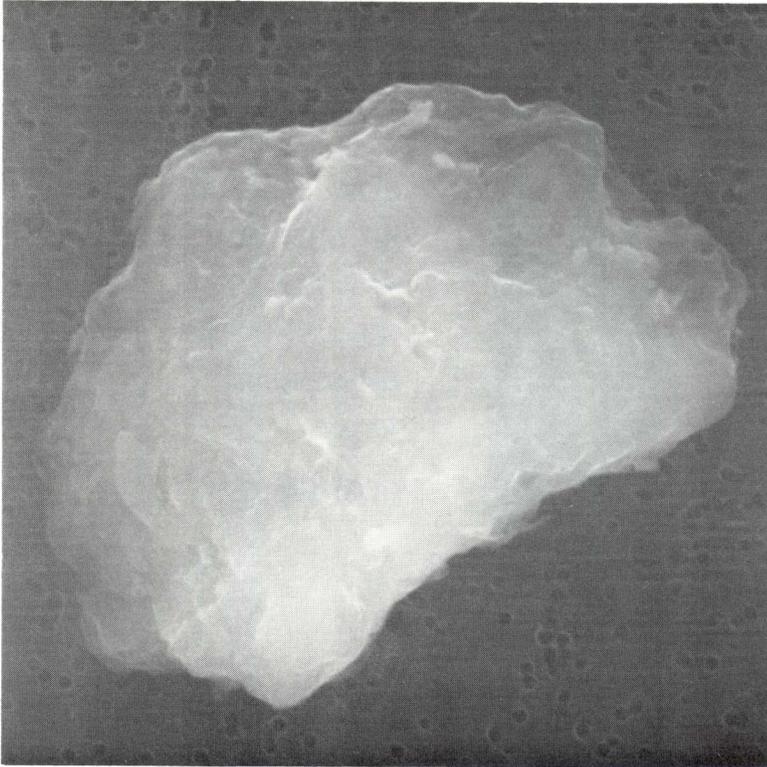
SIZE: 10x5
SHAPE: I
TRANS.: O
COLOR: Black to brown
LUSTER: D/SM
TYPE: ?
COMMENTS:

UB2

S-87-45945



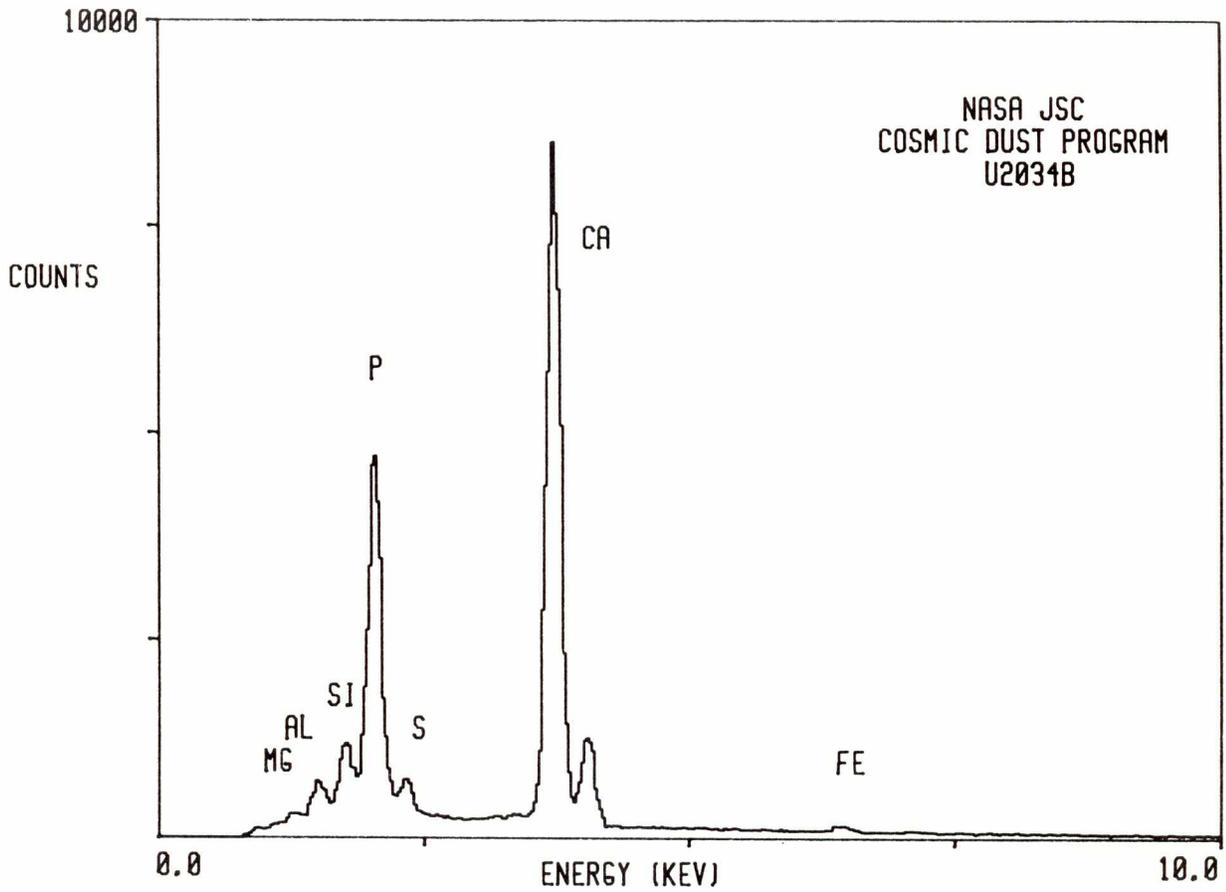
U2034 B 5



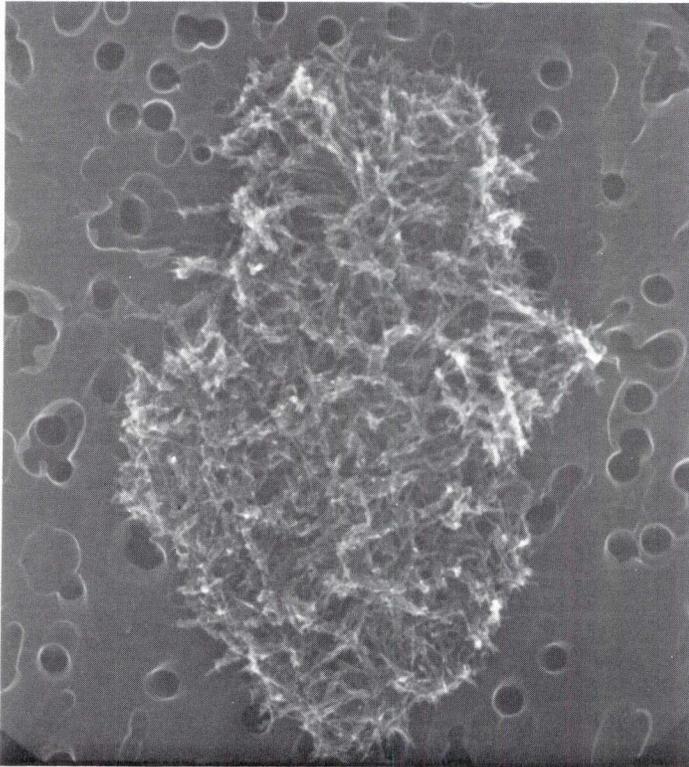
SIZE: 18x15
SHAPE: I
TRANS.: O
COLOR: Black to brown
LUSTER: D
TYPE: ?
COMMENTS:

UB5

S-87-45948



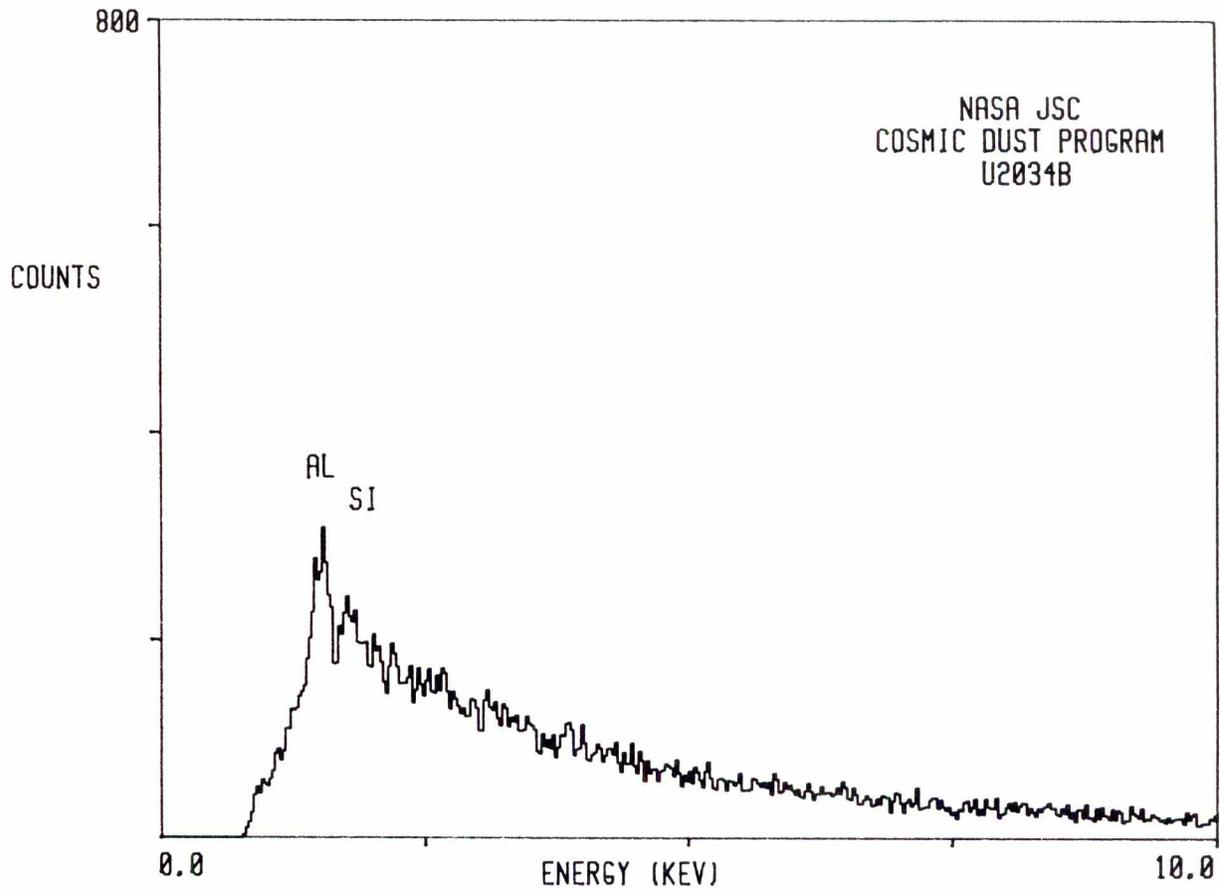
U2034 B 6



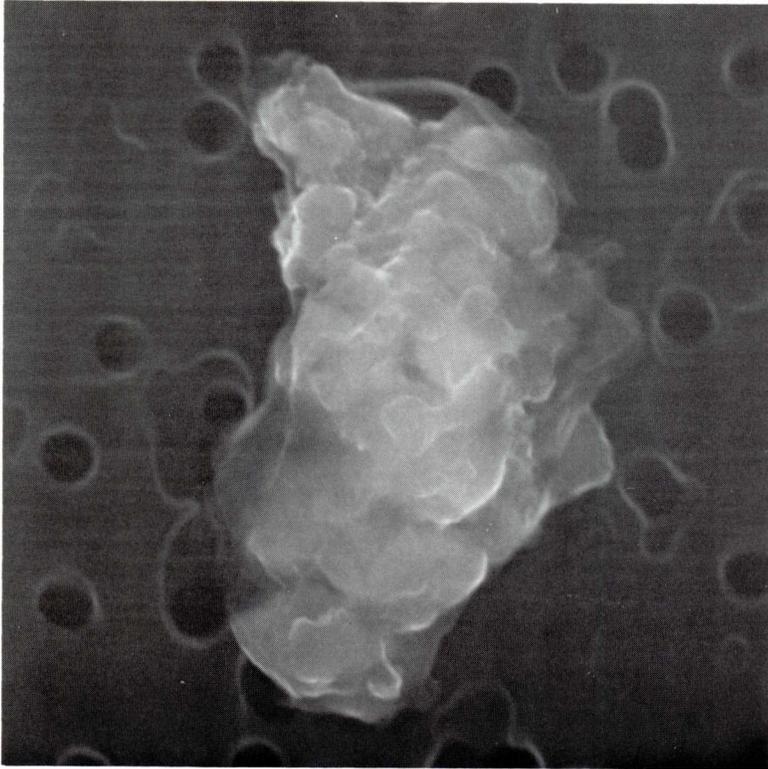
SIZE: 7x5
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?
COMMENTS:

UB6

S-87-45949



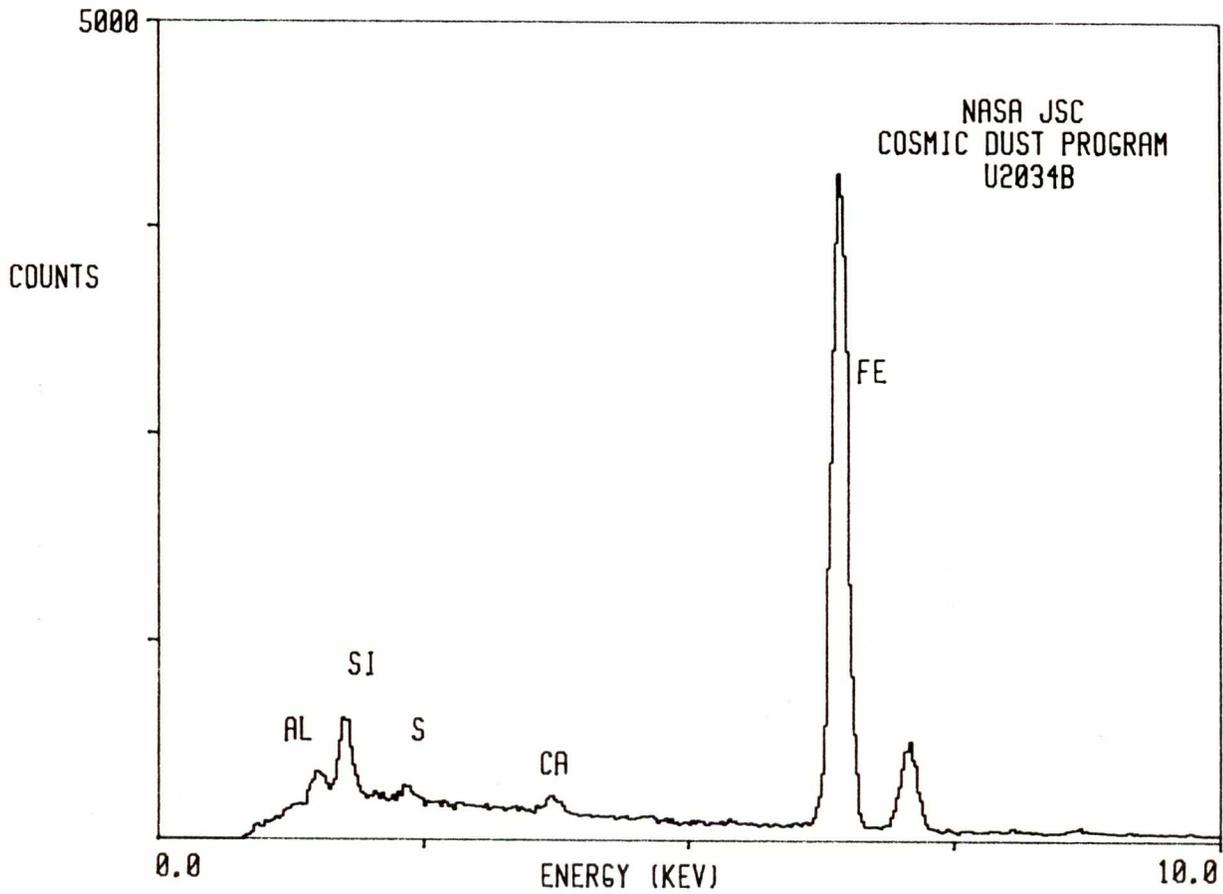
U2034 B 8



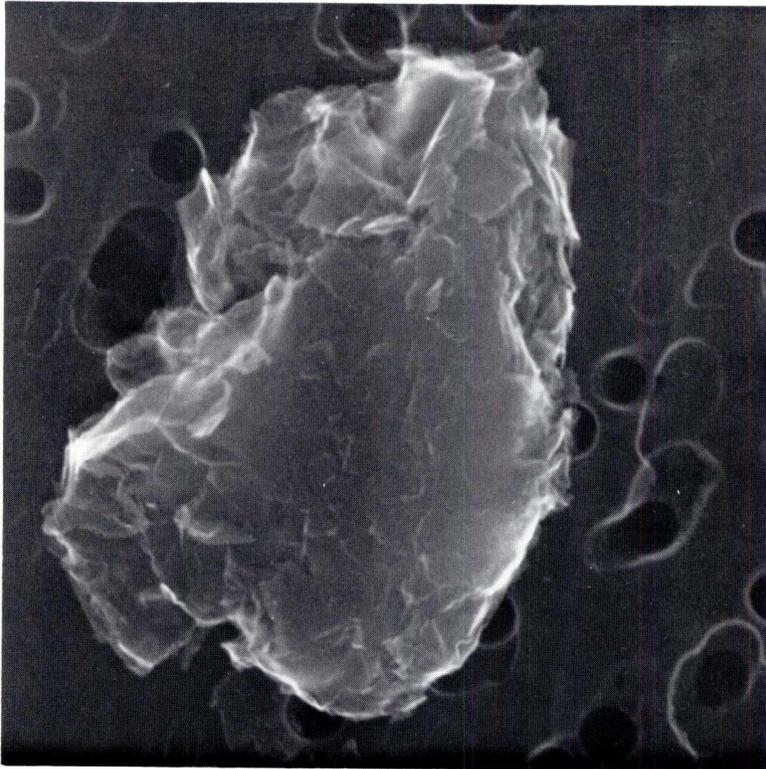
SIZE: 4x3
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?
COMMENTS:

UB8

S-87-45951



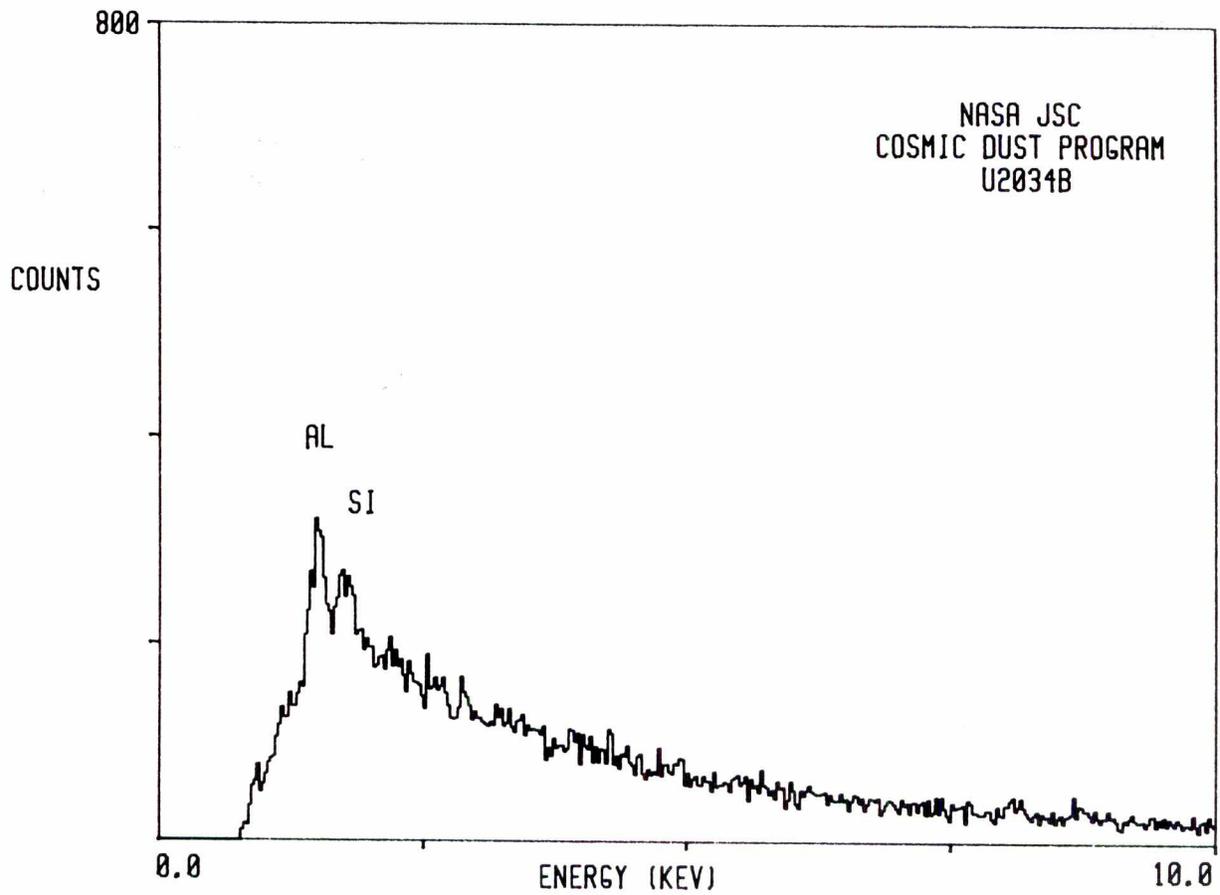
U2034 B 11



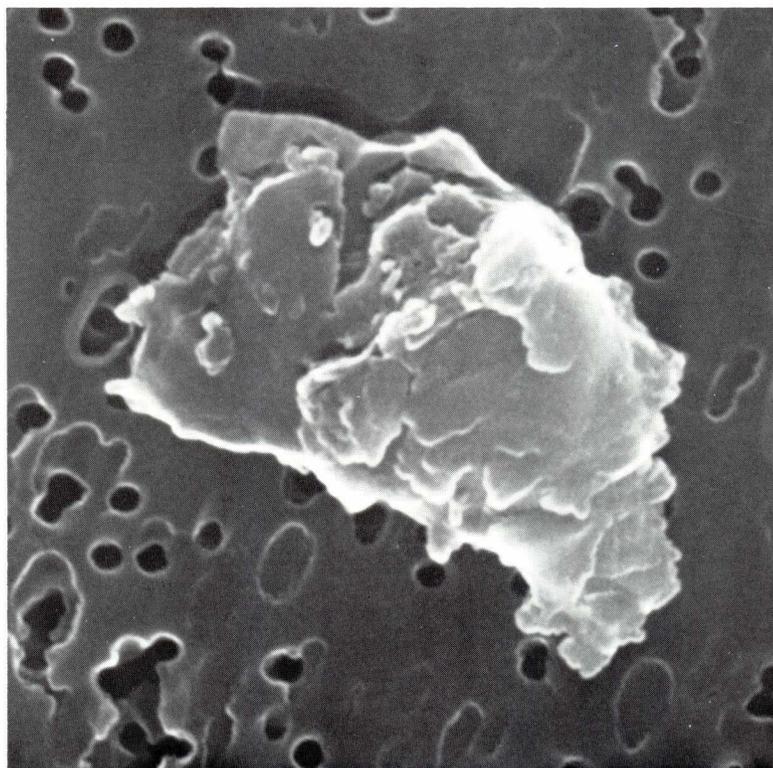
SIZE: 4
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?
COMMENTS:

UB11

S-87-45954



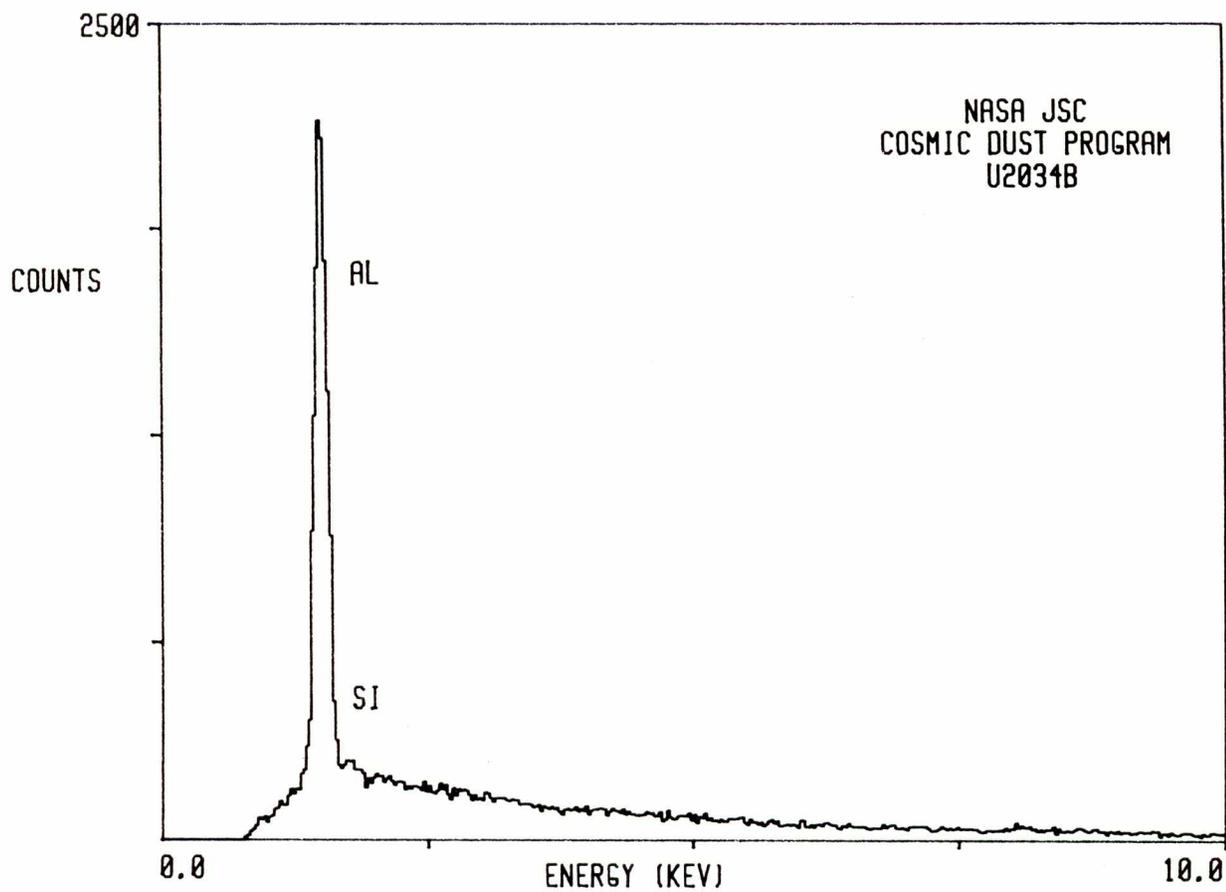
U2034 B 12



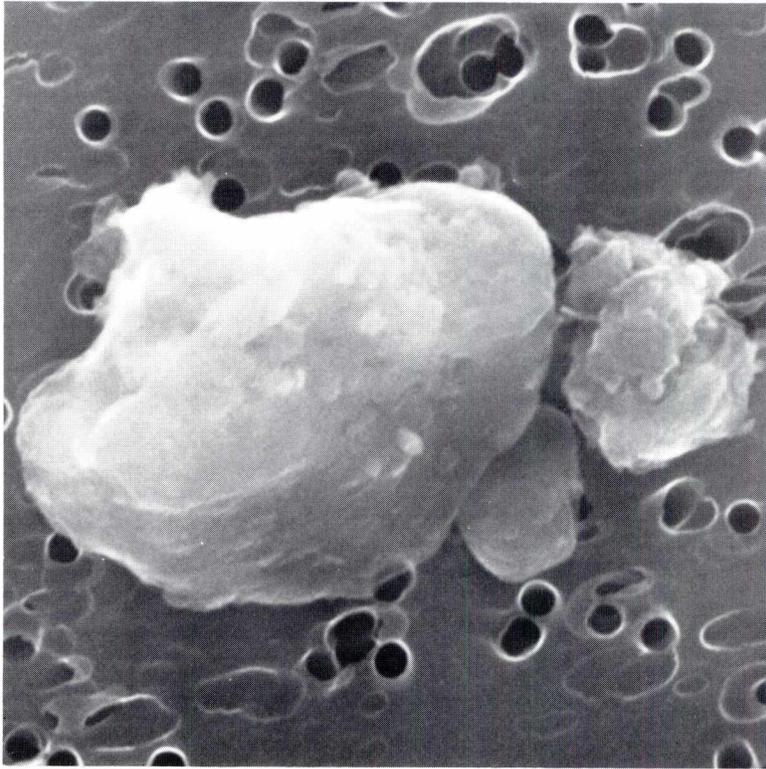
UB12

S-87-45955

SIZE: 4
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?
COMMENTS:



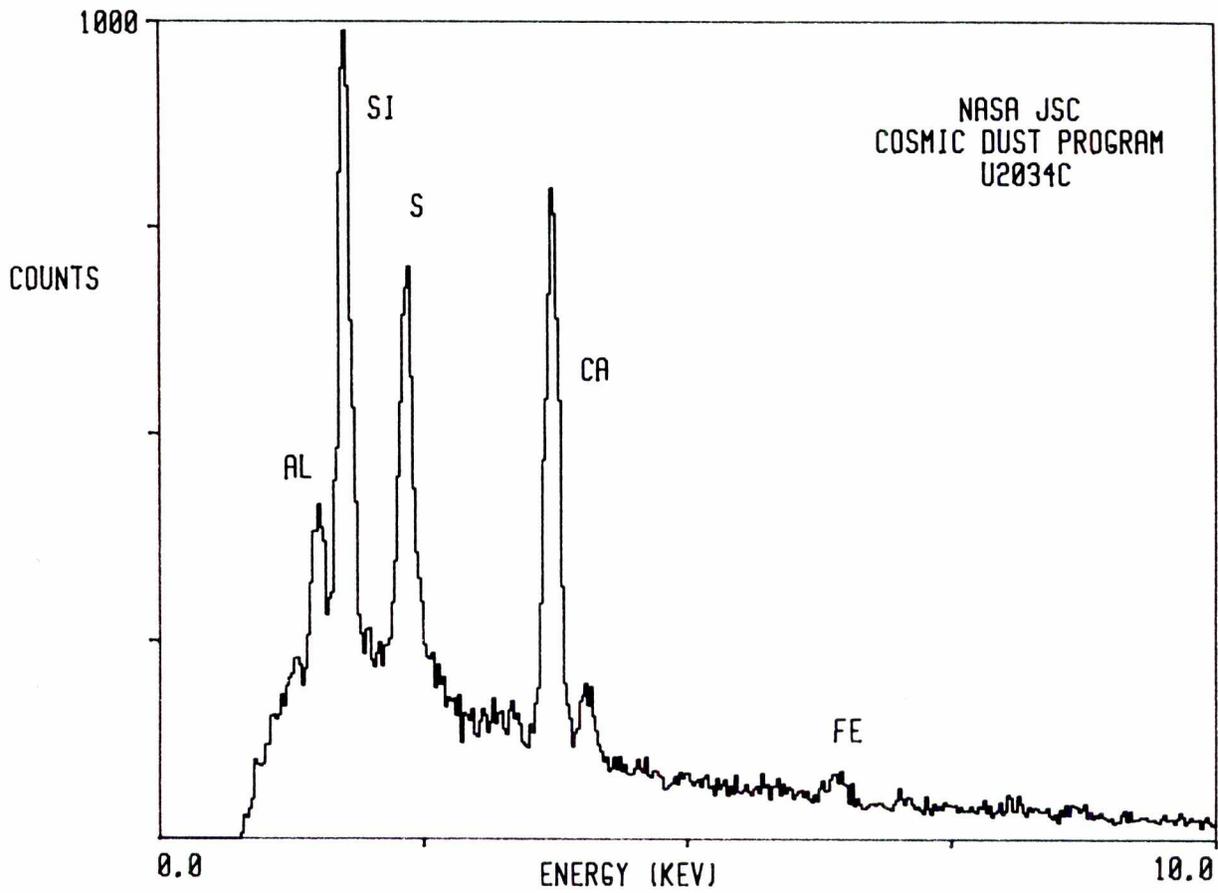
U2034 C 4



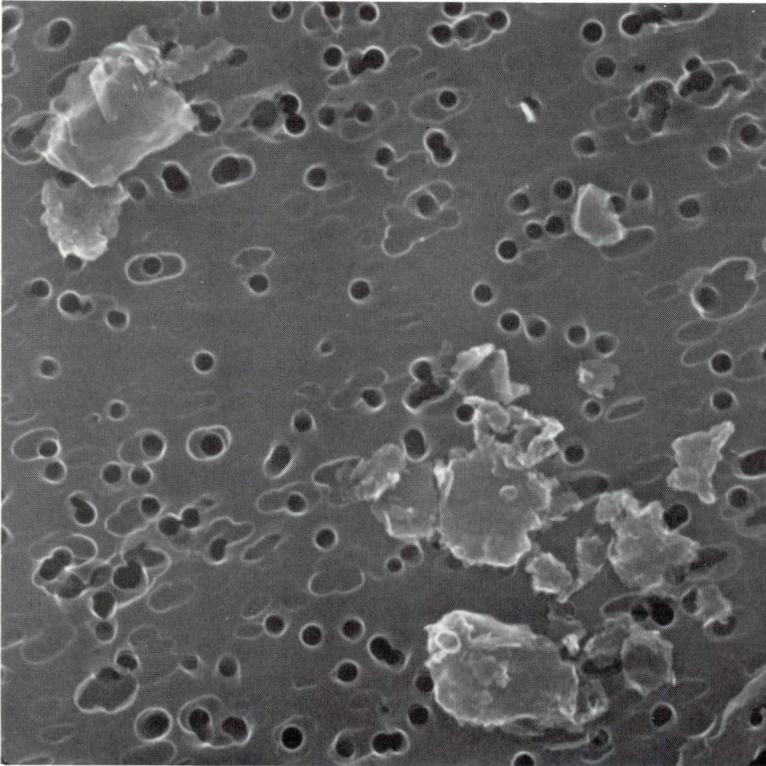
SIZE: 7x4
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?
COMMENTS:

UC4

S-87-45964



U2034 C 7

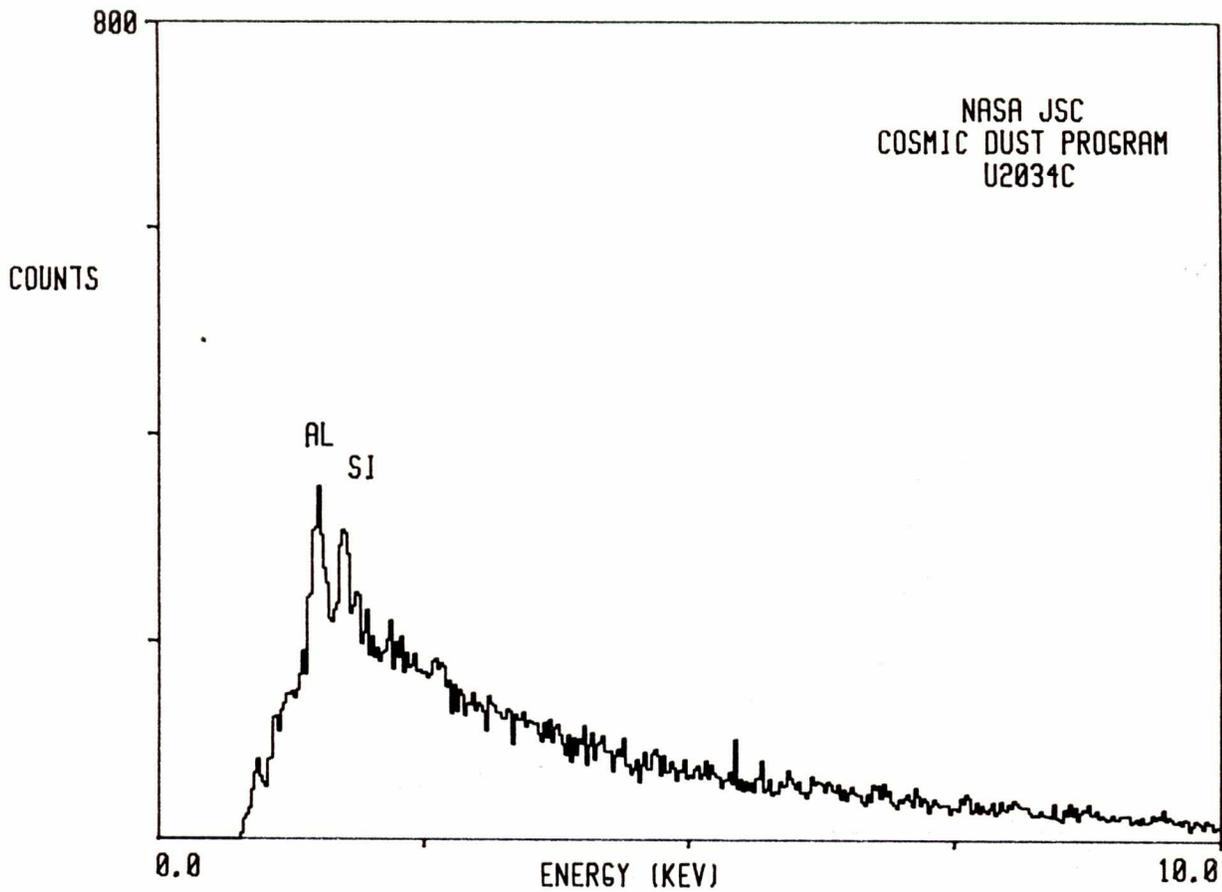


SIZE:
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?

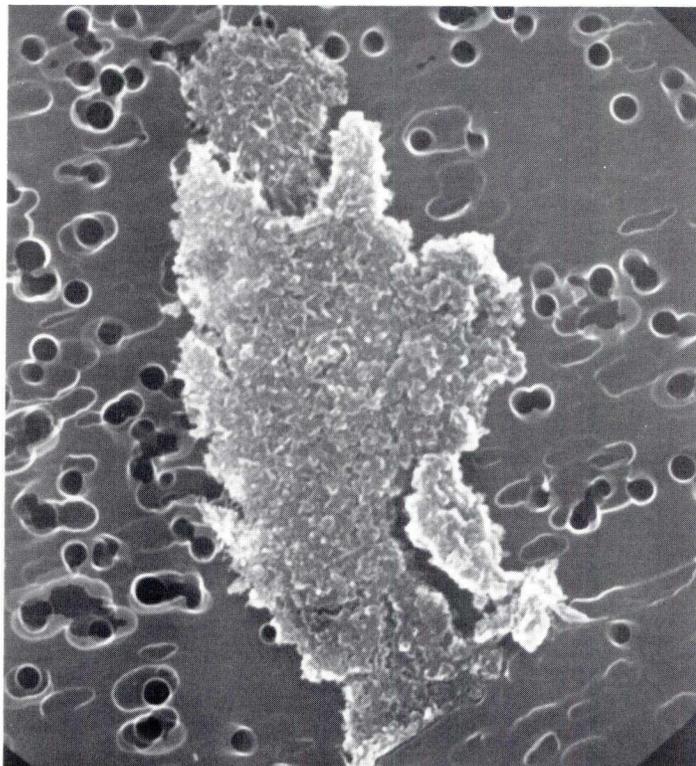
COMMENTS:
Large field of
small particles

UC7

S-87-45965



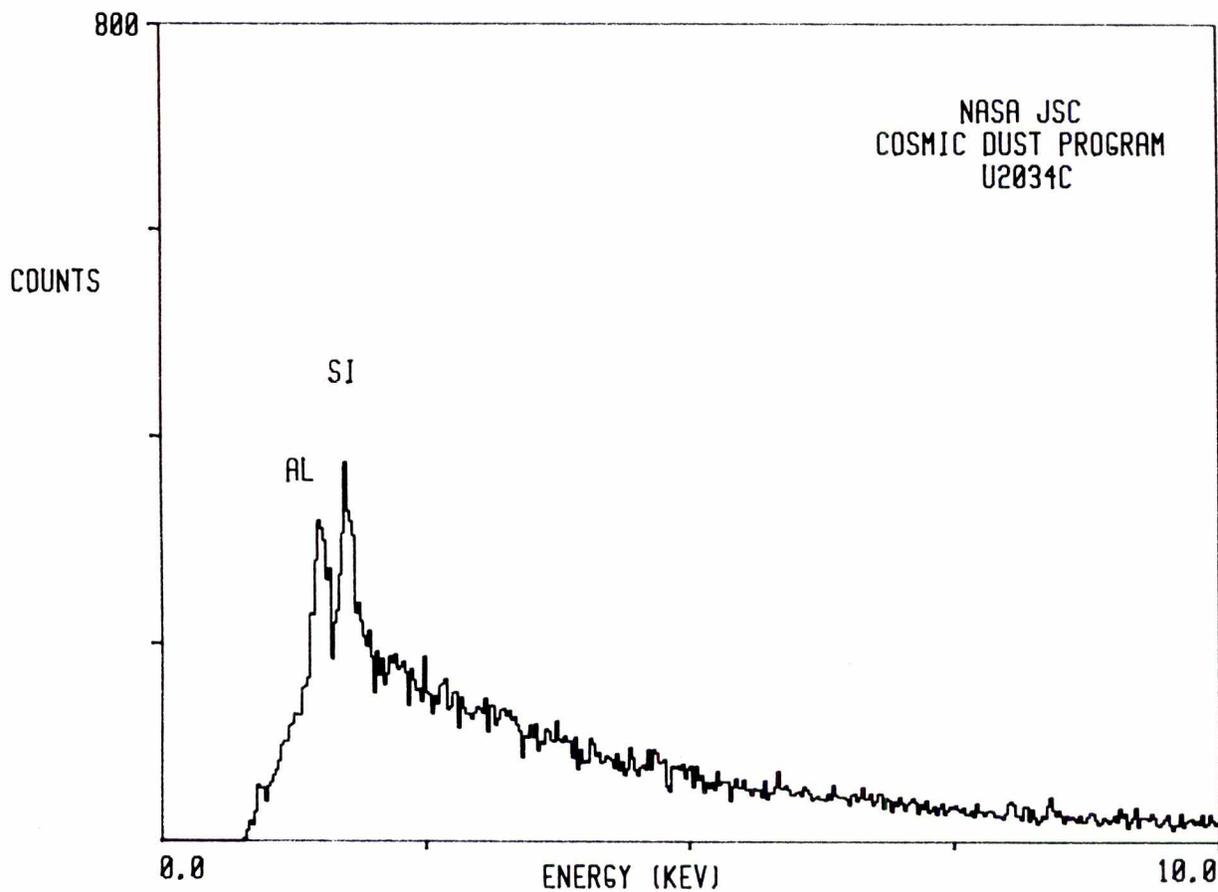
U2034 C 11



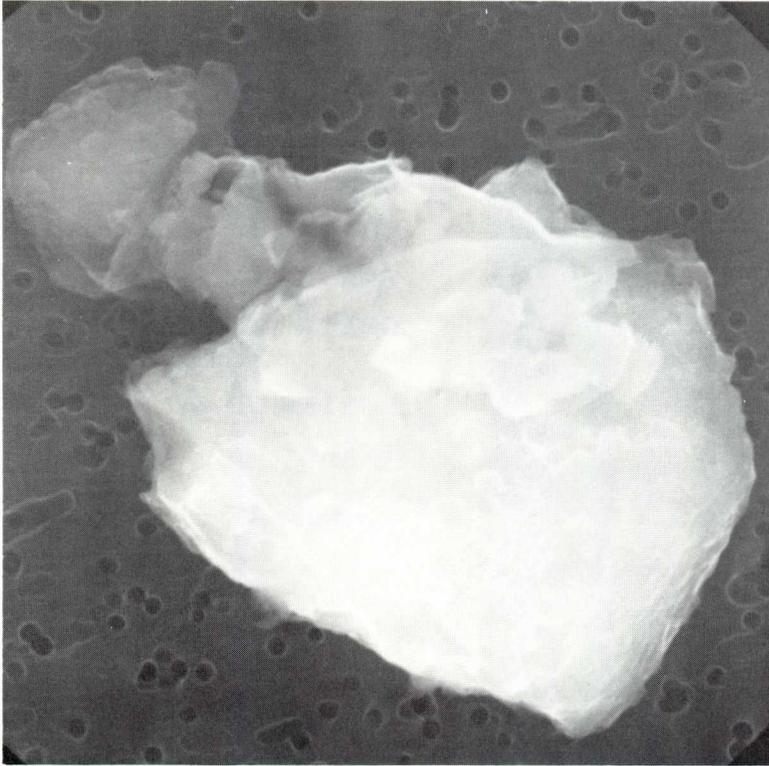
SIZE: 10x4
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?
COMMENTS:

UC11

S-87-45971



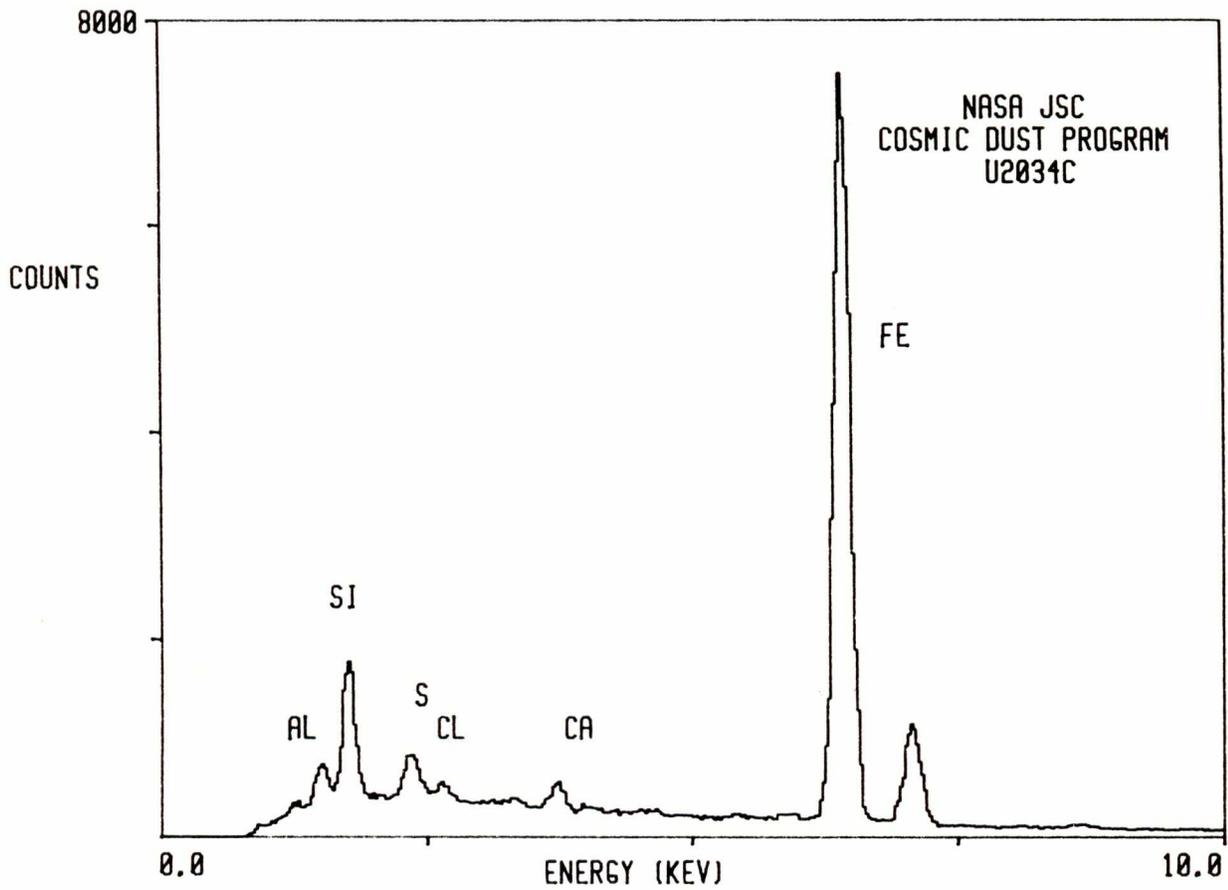
U2034 C 15



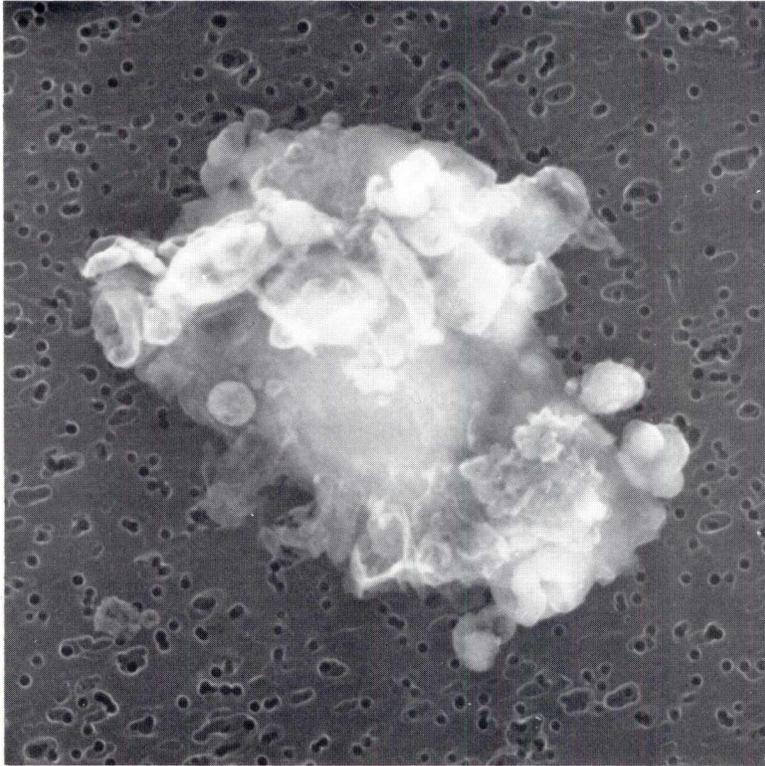
SIZE: 10
SHAPE: I
TRANS.: O
COLOR: Black to grey
LUSTER: D/SM
TYPE: ?
COMMENTS:

UC15

S-87-45967



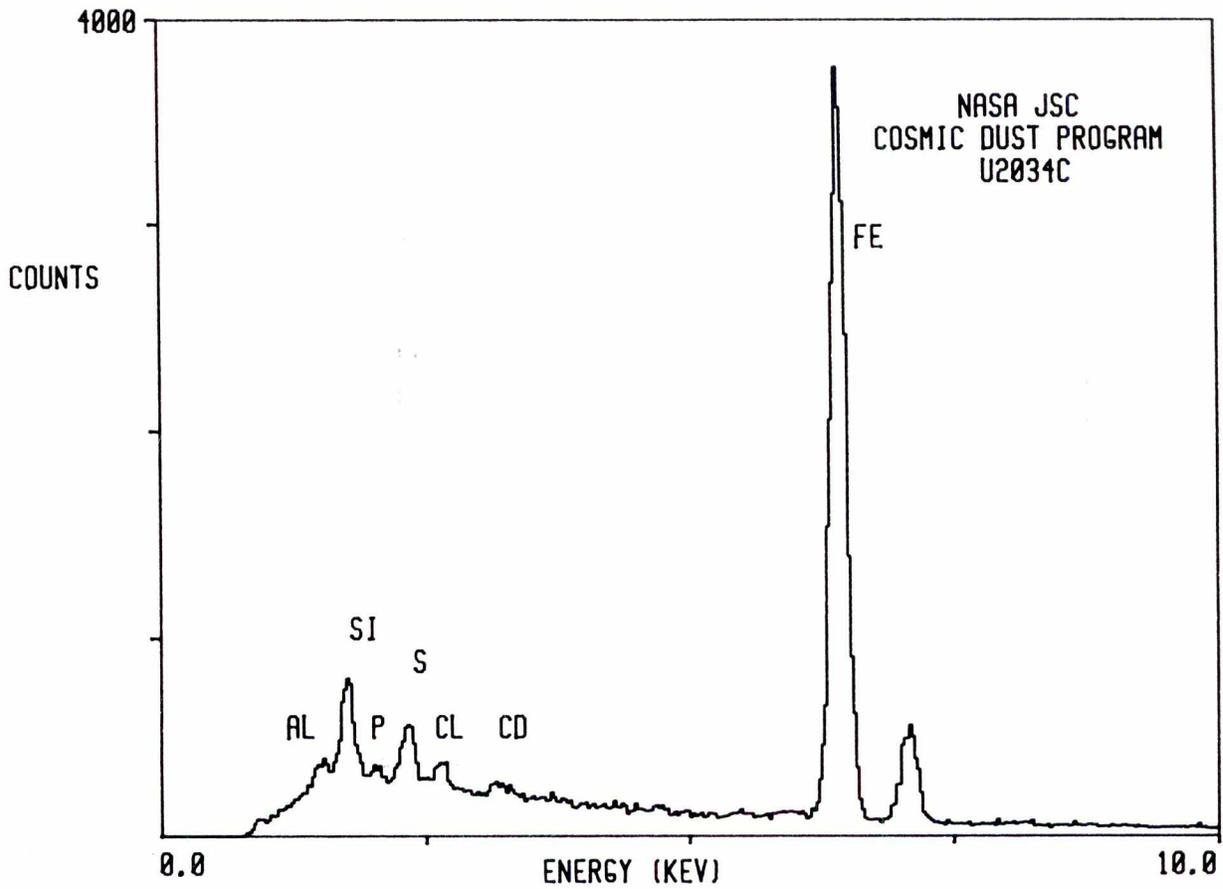
U2034 C 16



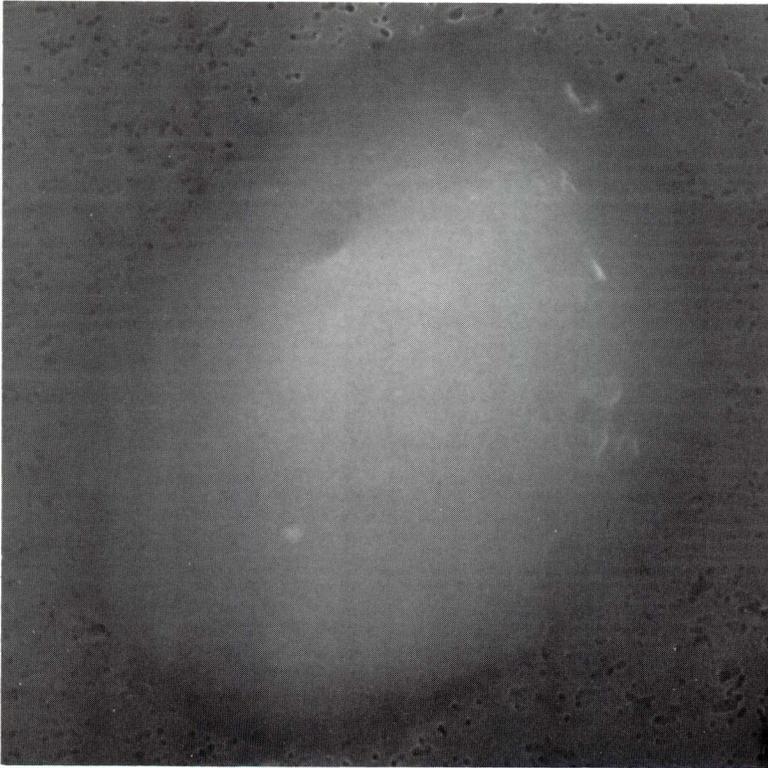
UC16

S-87-45976

SIZE: 20x12
SHAPE: I
TRANS.: O/TL
COLOR: Black to red-brown
LUSTER: D/SV
TYPE: ?
COMMENTS:

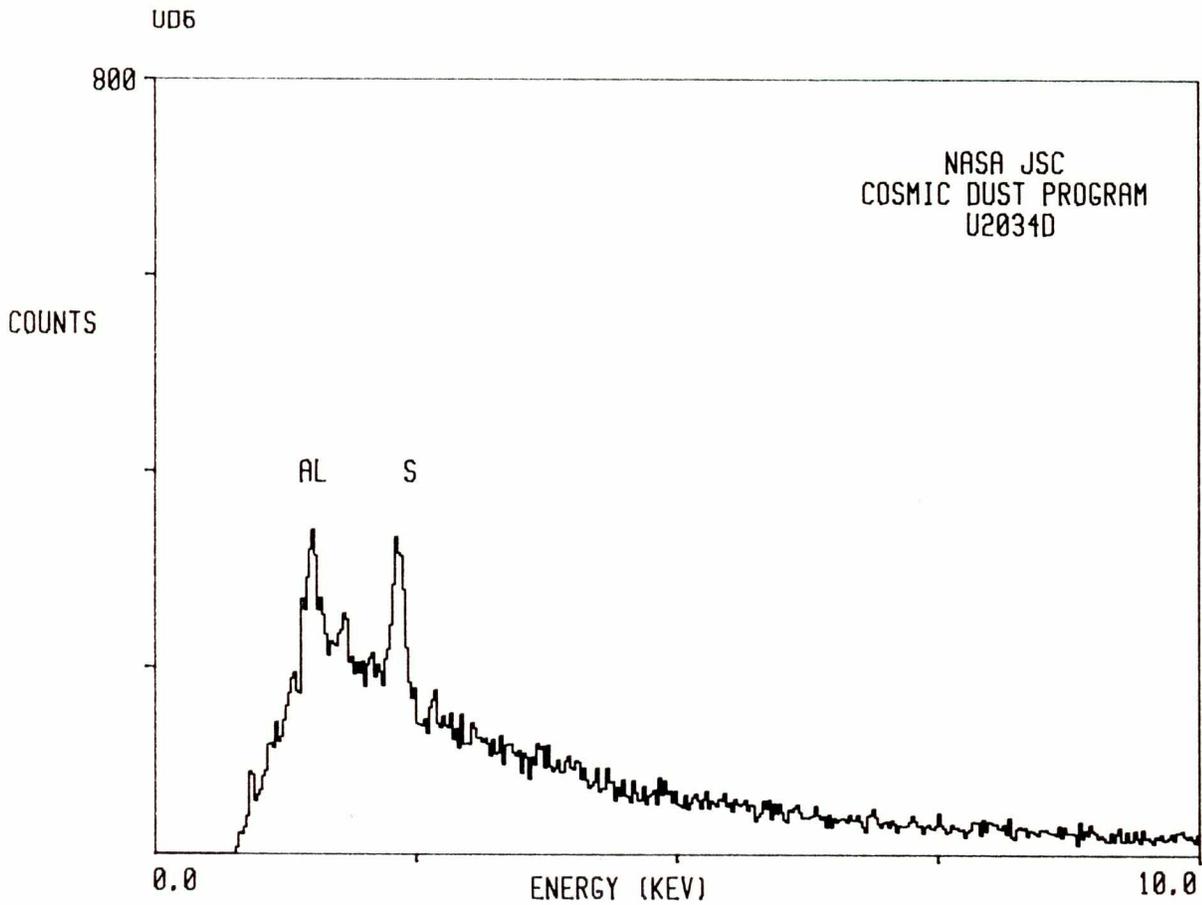


U2034 D 6

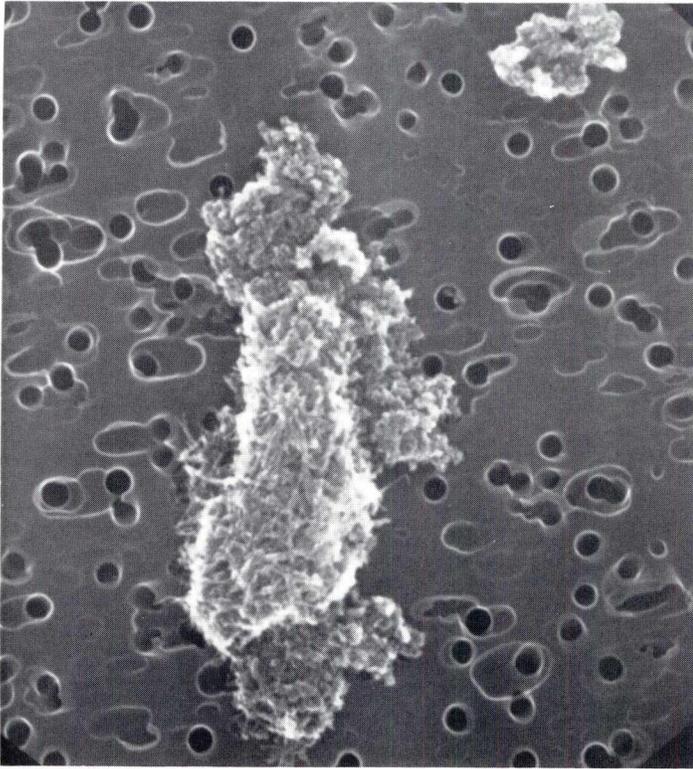


SIZE: 30x25
SHAPE: S
TRANS.: O
COLOR: Black
LUSTER: SM
TYPE: ?
COMMENTS:

S-87-45984



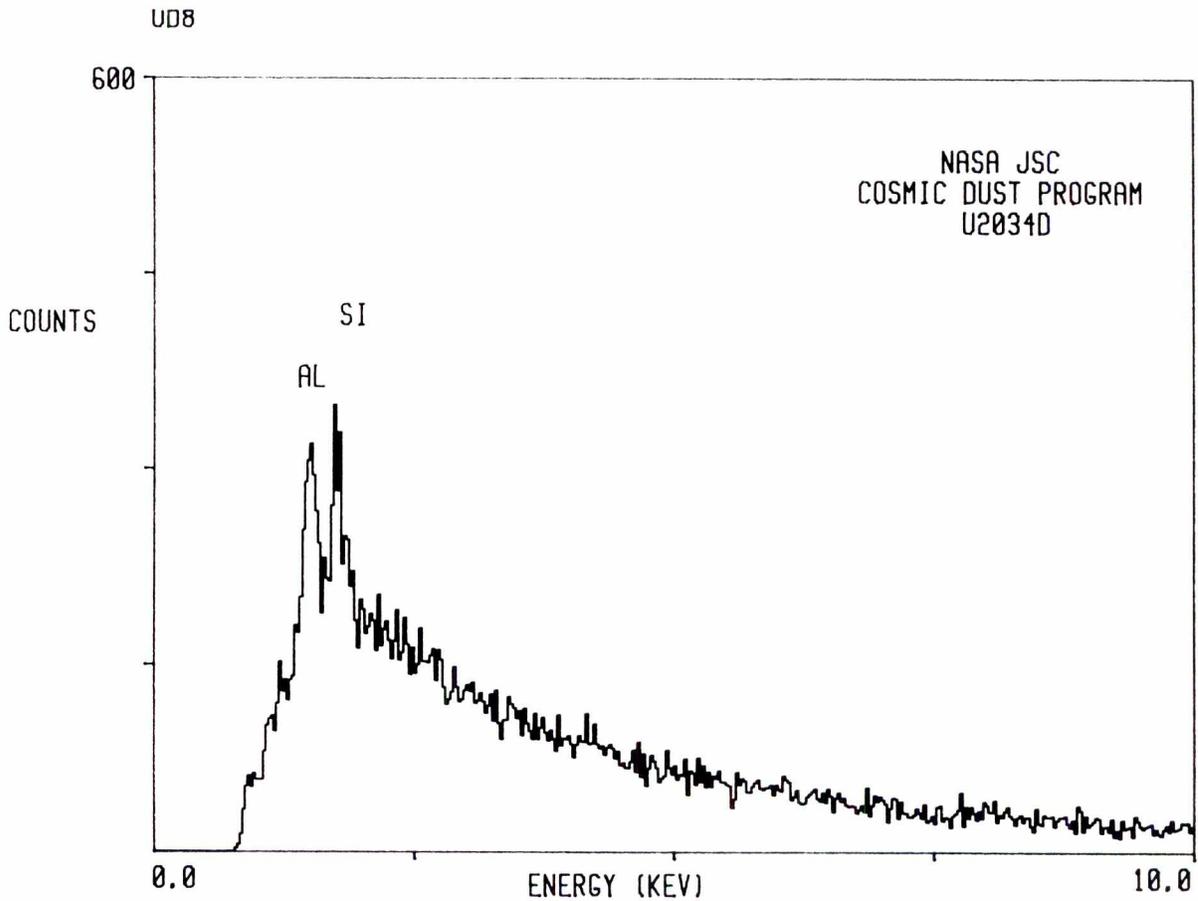
U2034 D 8



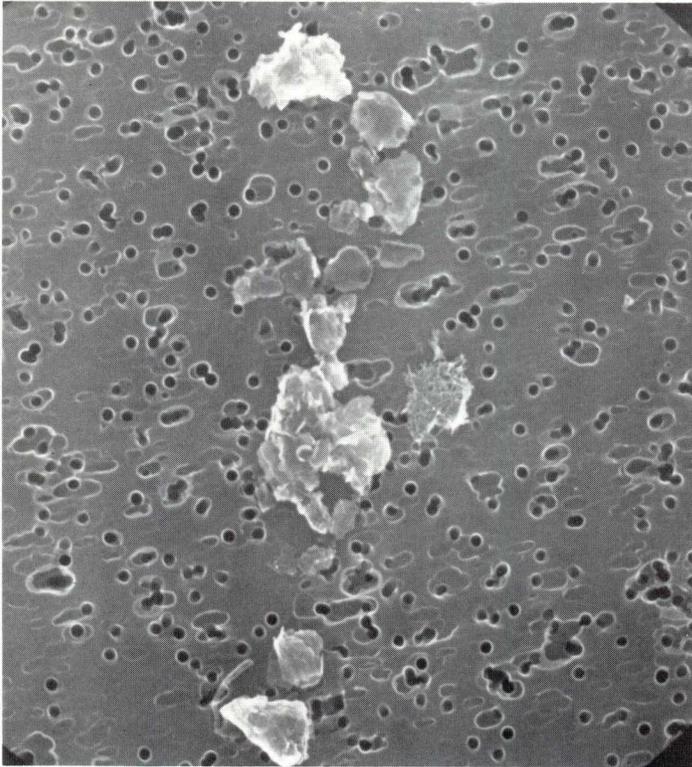
SIZE: 22x20
SHAPE: I
TRANS.: O/TL
COLOR: Yellow to white
LUSTER: D/SV
TYPE: ?

COMMENTS:
Field of dispersed
particles

S-87-45986



U2034 D 10

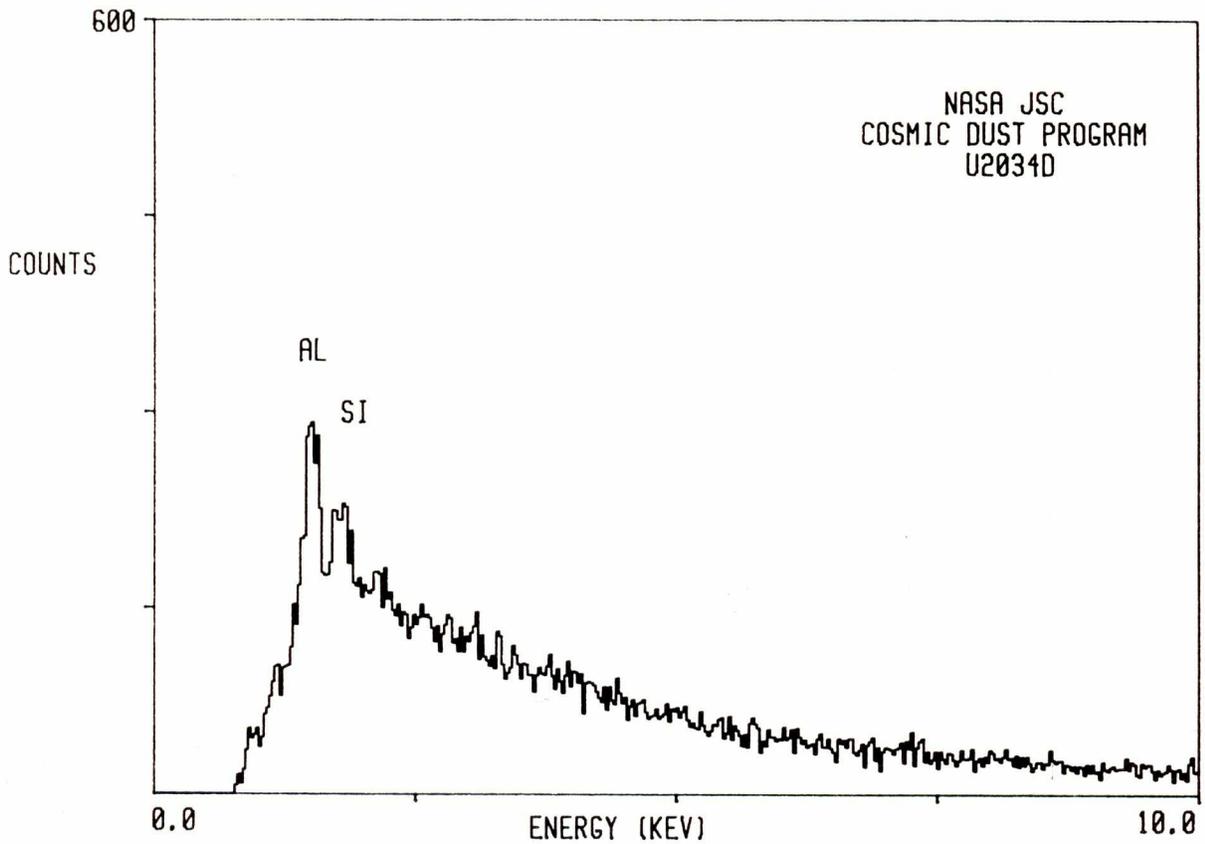


SIZE: 20x15
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?

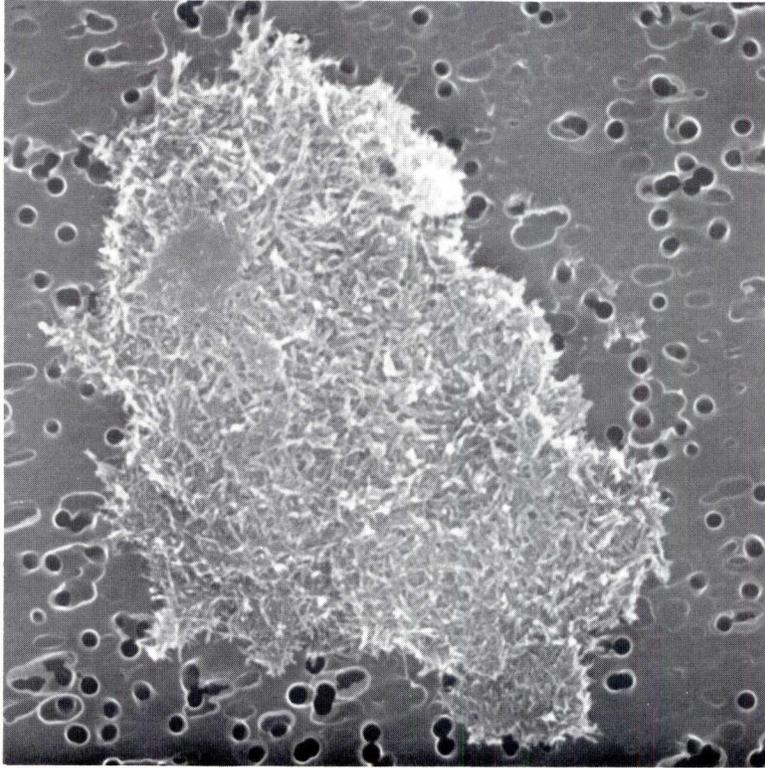
COMMENTS:
Size of largest
particle in a
field of particles

S-87-45988

UD10

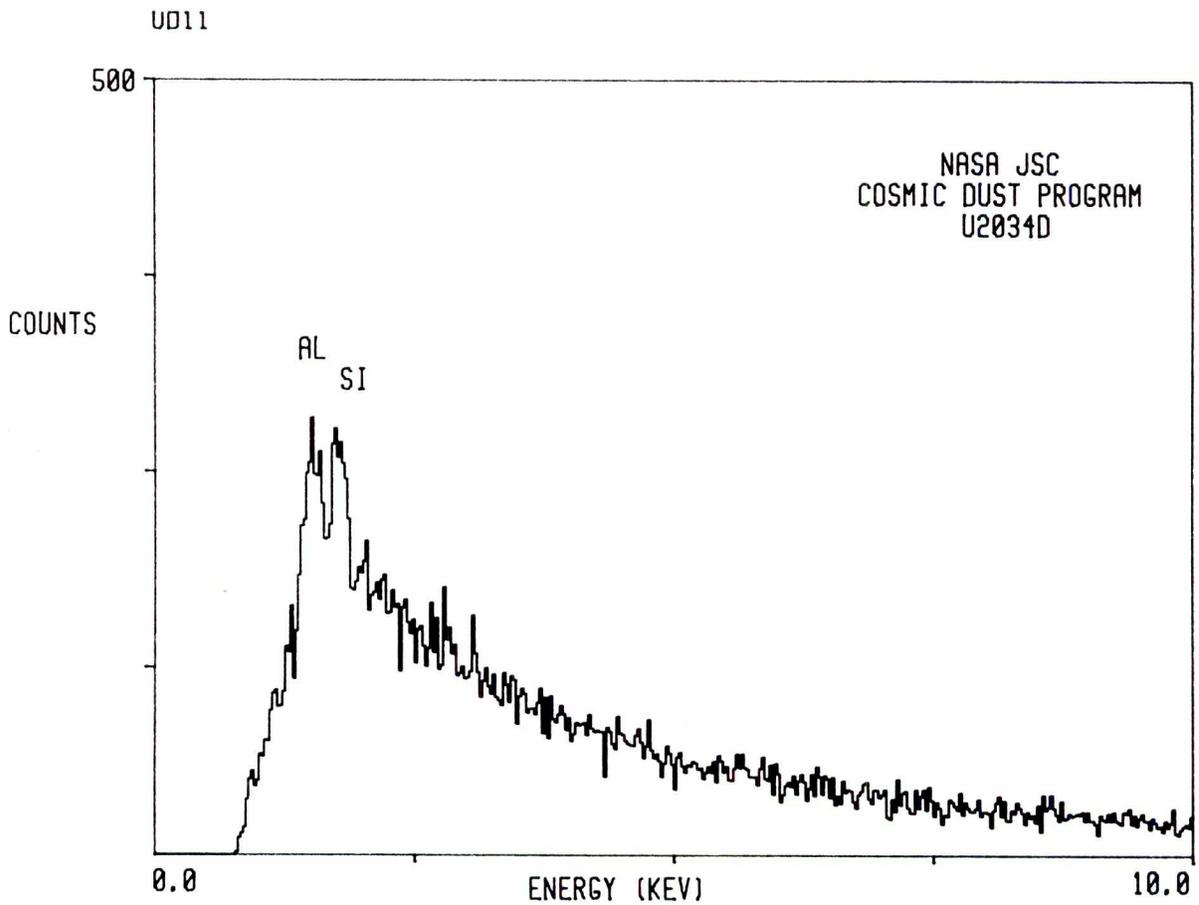


U2034 D 11

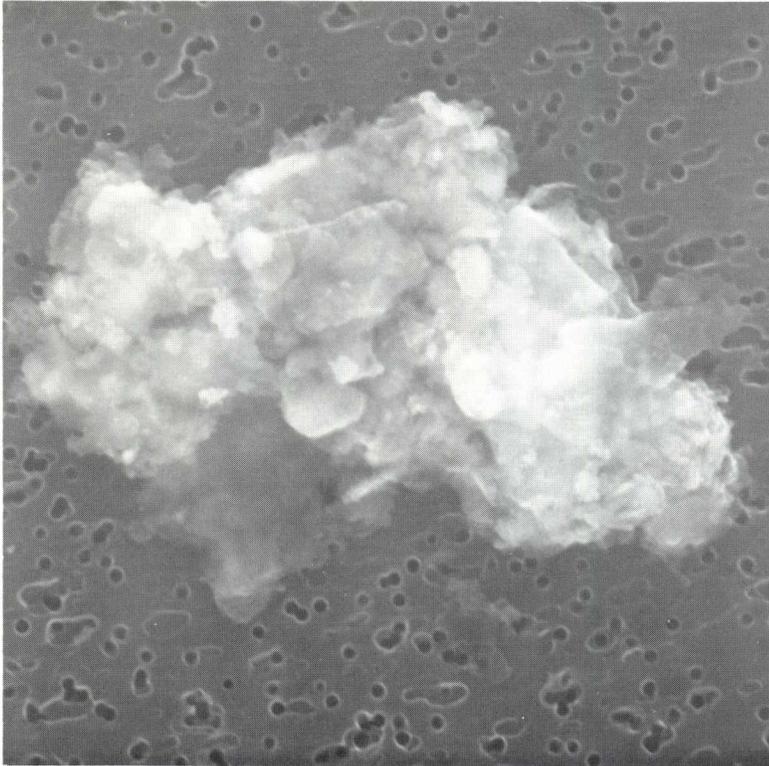


SIZE: 15
SHAPE: S
TRANS.: TL
COLOR: Yellow
LUSTER: SV
TYPE: ?
COMMENTS:

S-87-45989

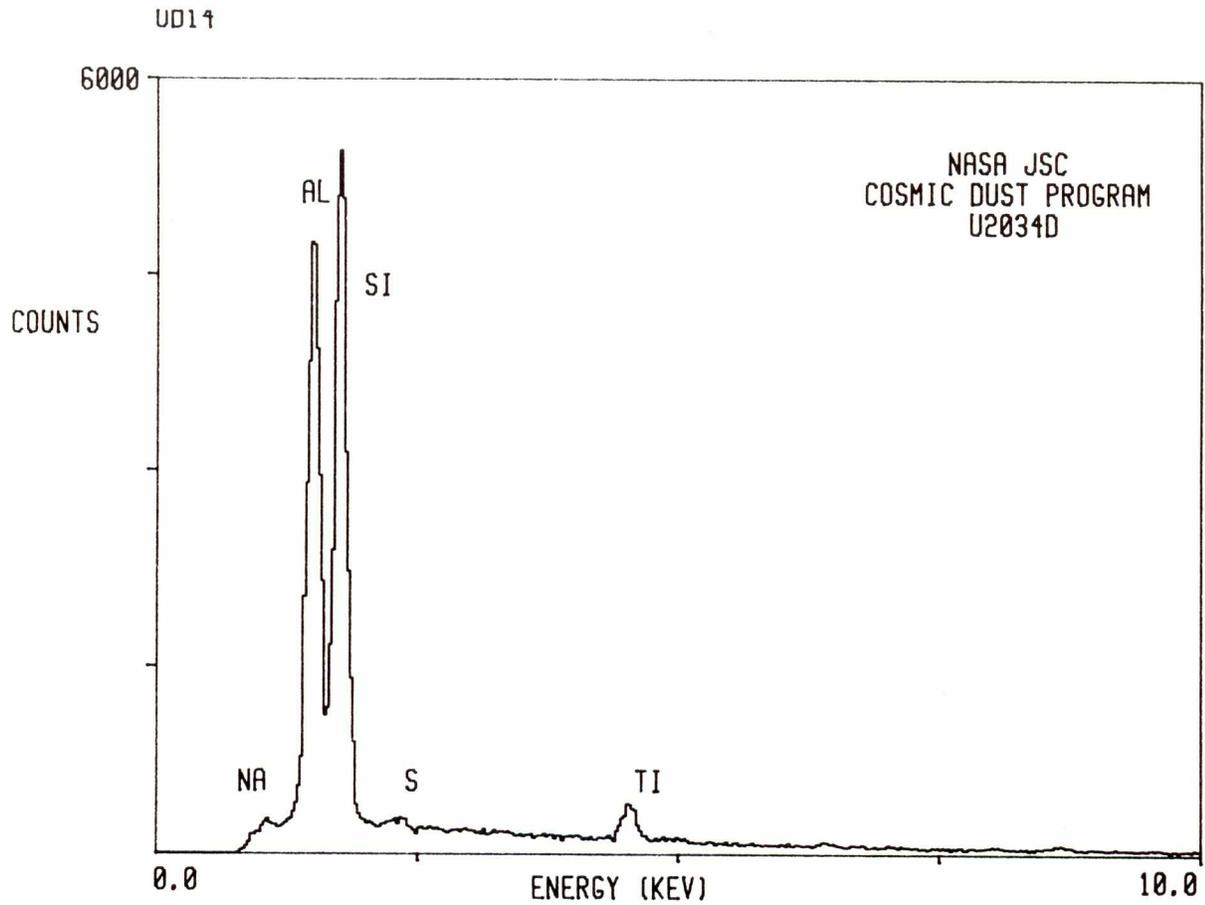


U2034 D 14

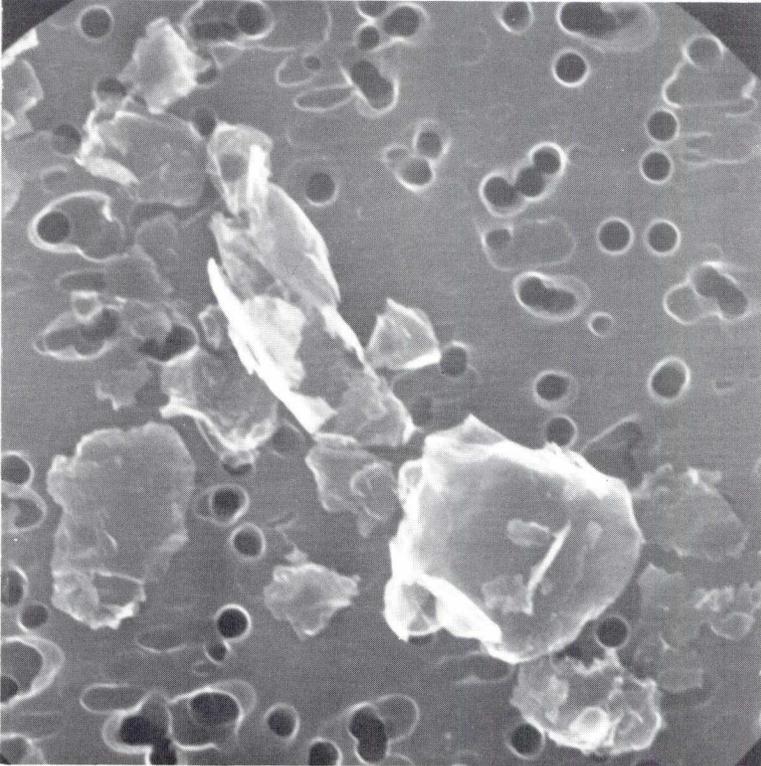


SIZE: 15x8
SHAPE: I
TRANS.: O/TL
COLOR: Black to gold
LUSTER: D/SV
TYPE: ?
COMMENTS:

S-87-45991



U2034 D 15



SIZE: 22x12

SHAPE: I

TRANS.: O

COLOR: Black

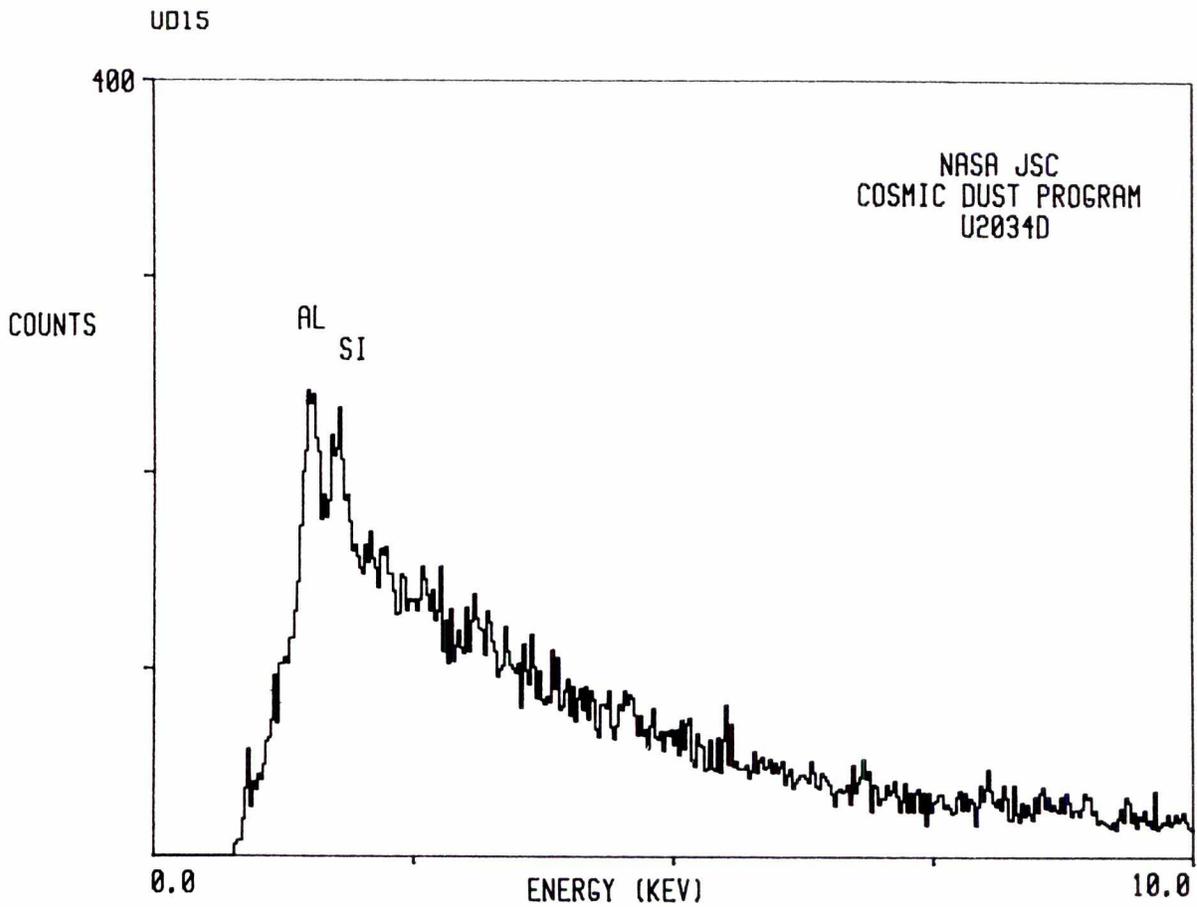
LUSTER: D

TYPE: ?

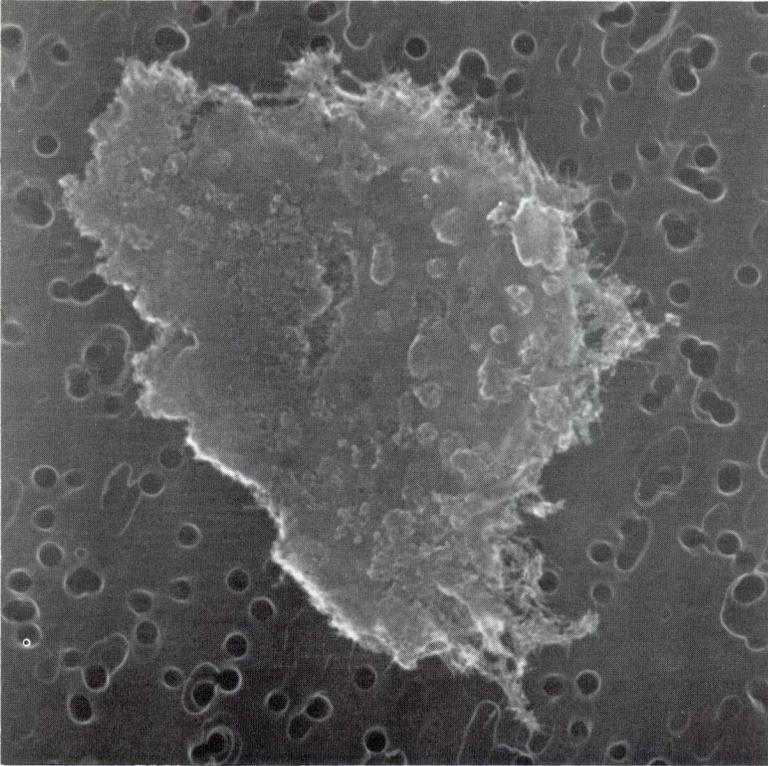
COMMENTS:

Field of particles

S-87-45992

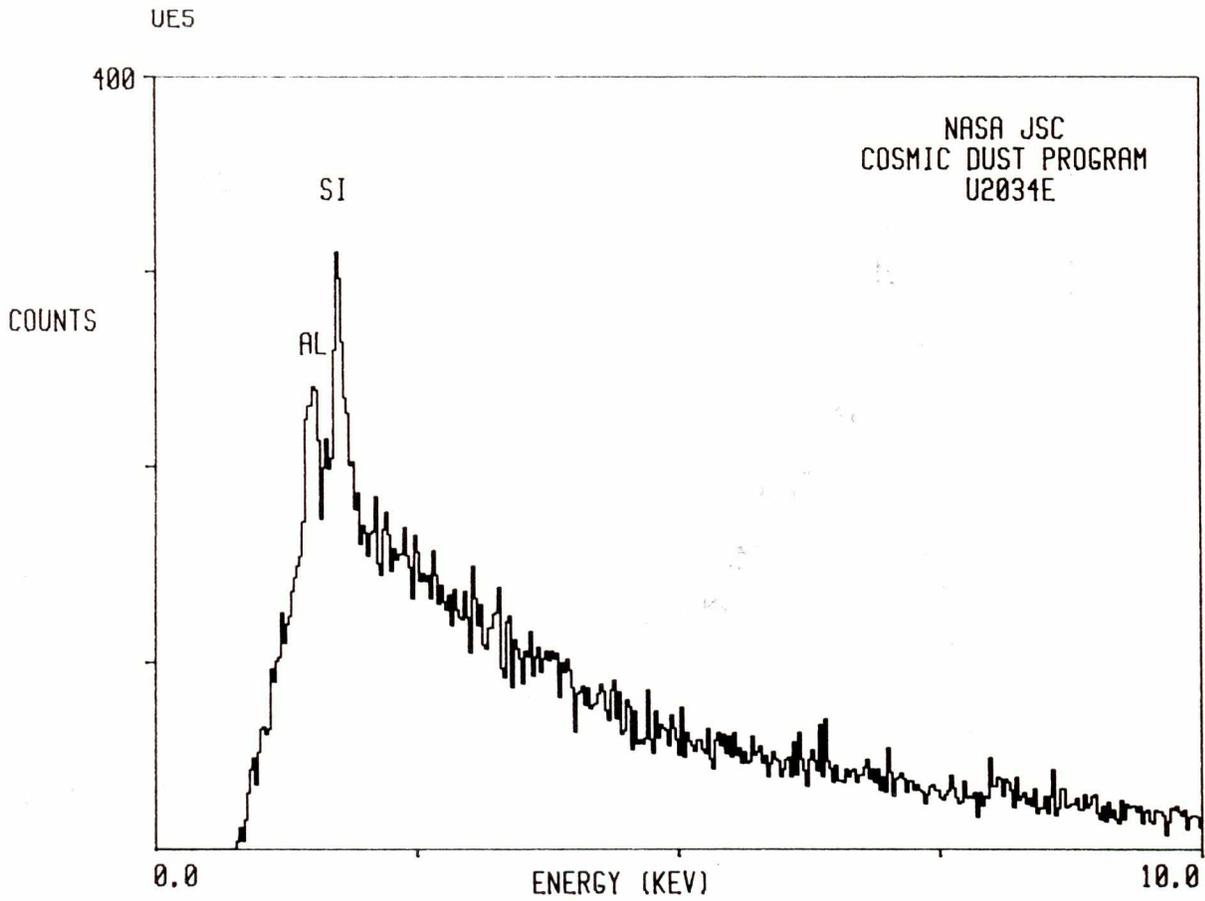


U2034 E 5

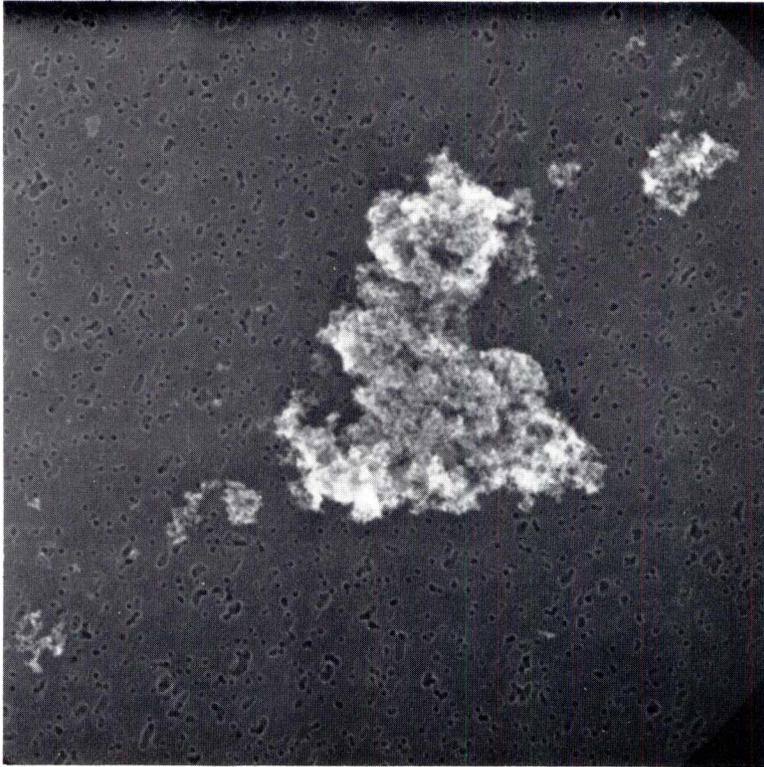


SIZE: 10
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?
COMMENTS:

S-87-46001



U2034 E 9

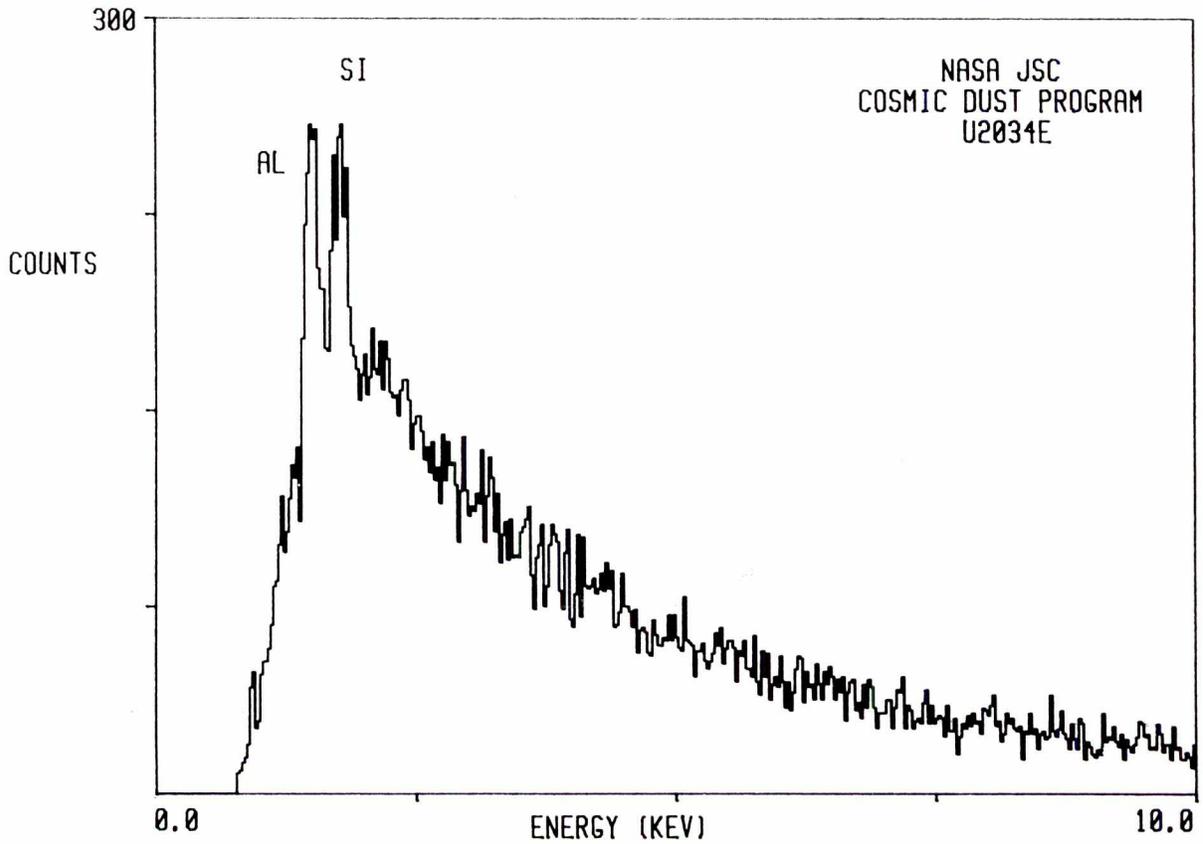


SIZE: 20x18
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?

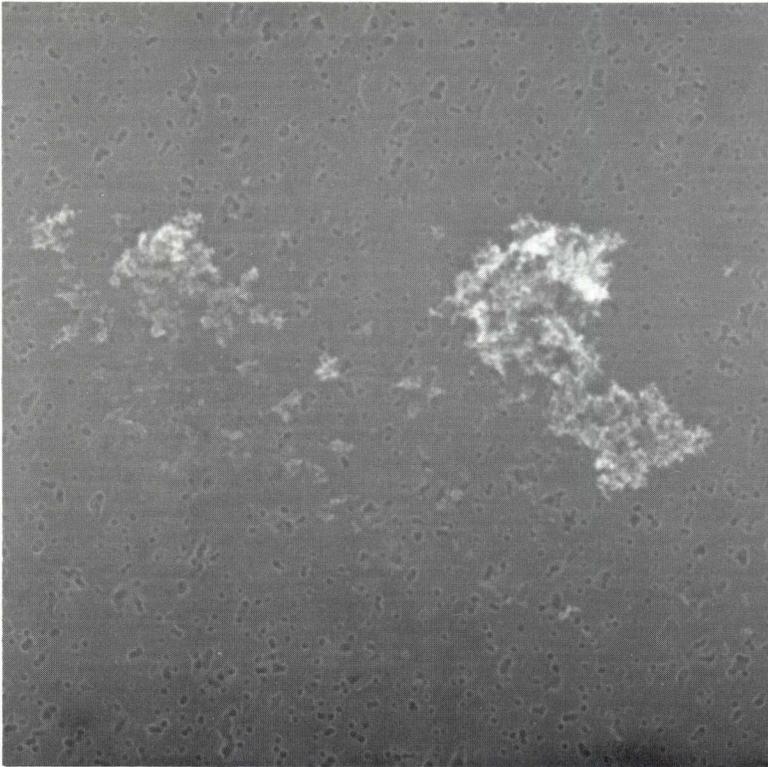
COMMENTS:
May be related to
U2034E10

S-87-46005

UE9



U2034 E 10



SIZE: 15x10

SHAPE: I

TRANS.: O

COLOR: Black

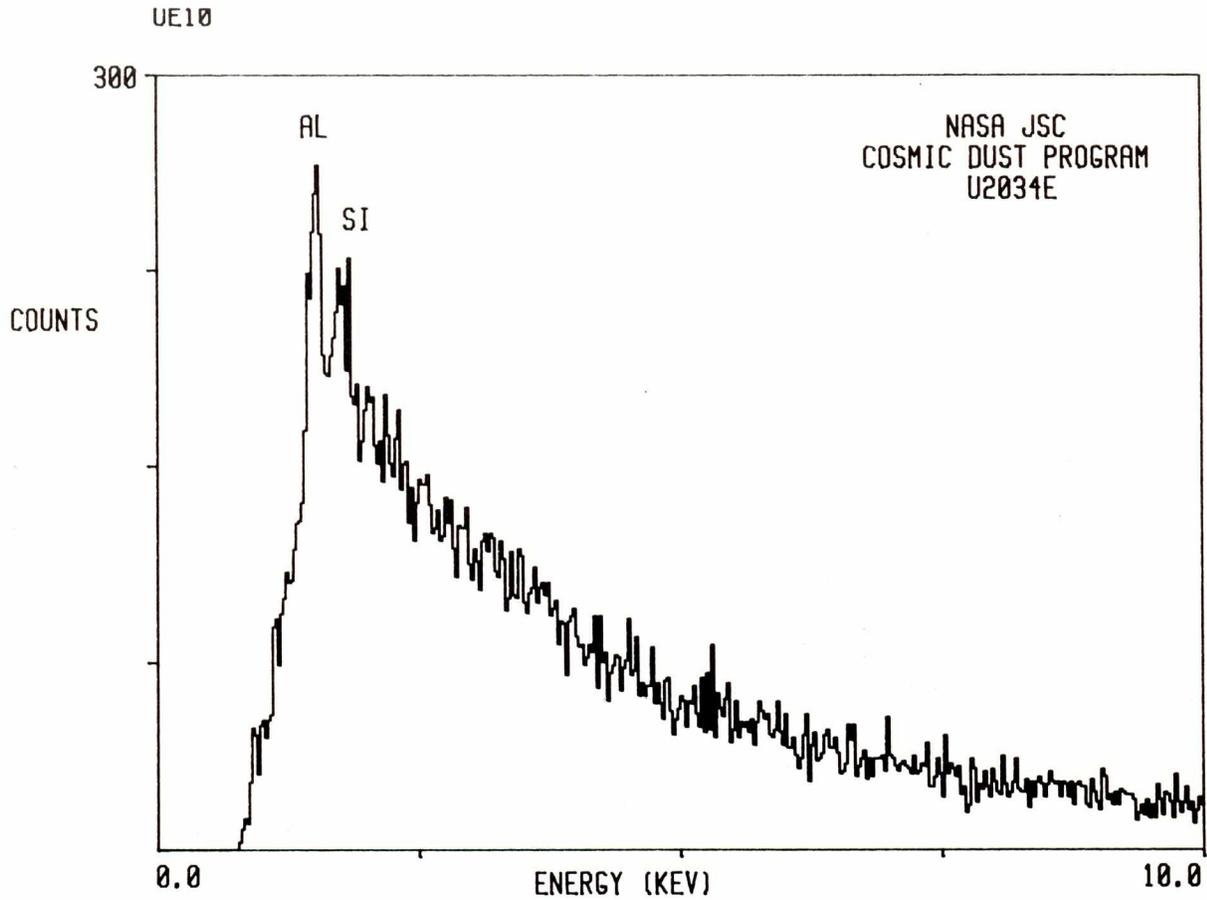
LUSTER: D

TYPE: ?

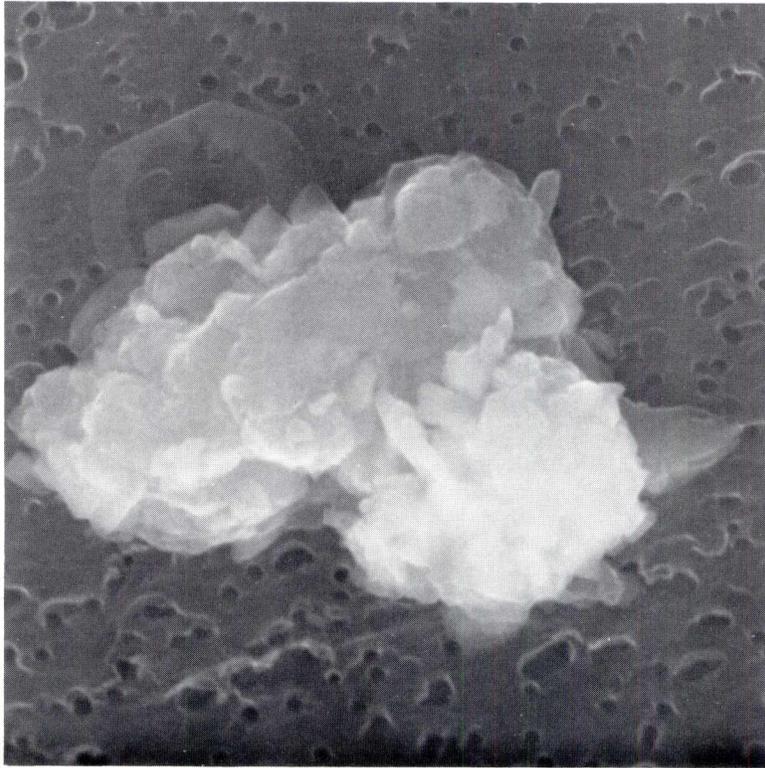
COMMENTS:

May be related to
U2034E9

S-87-46006

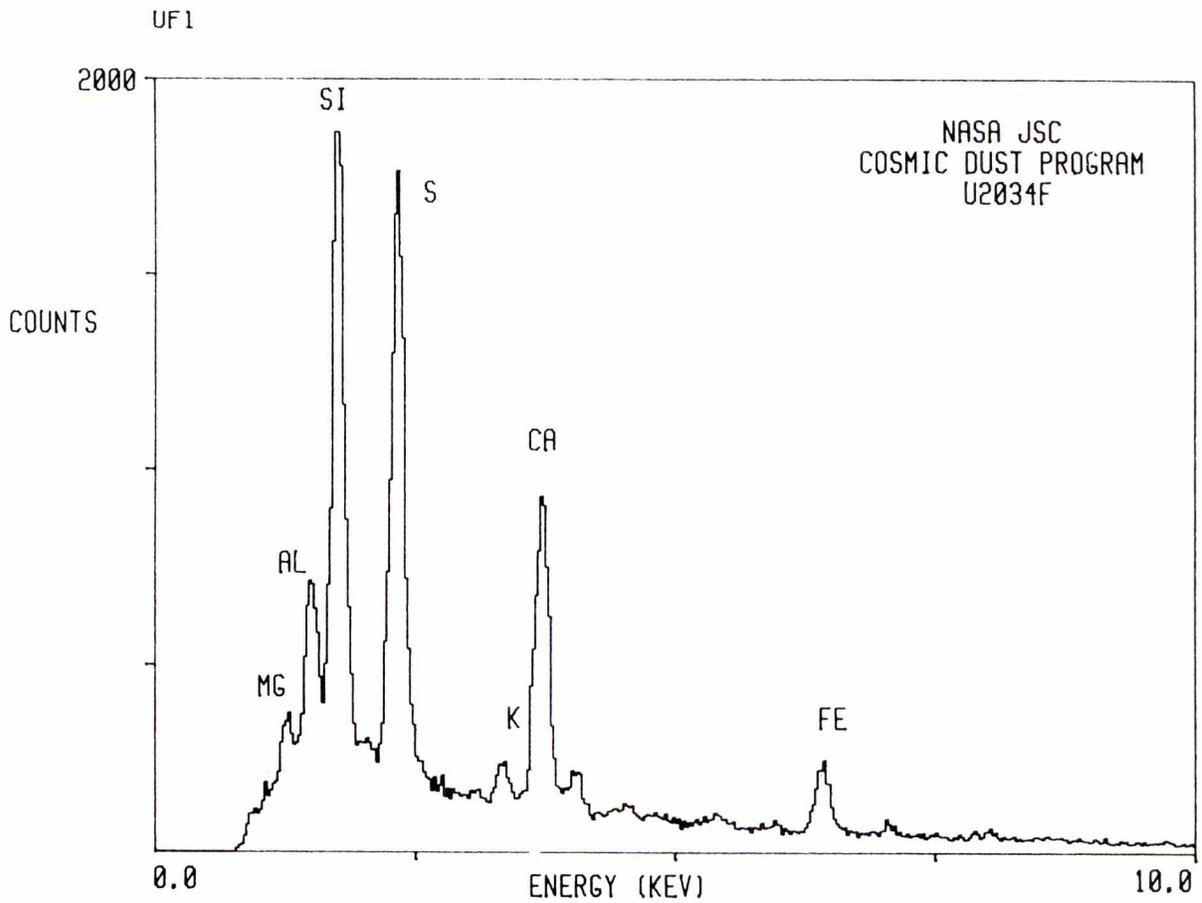


U2034 F 1

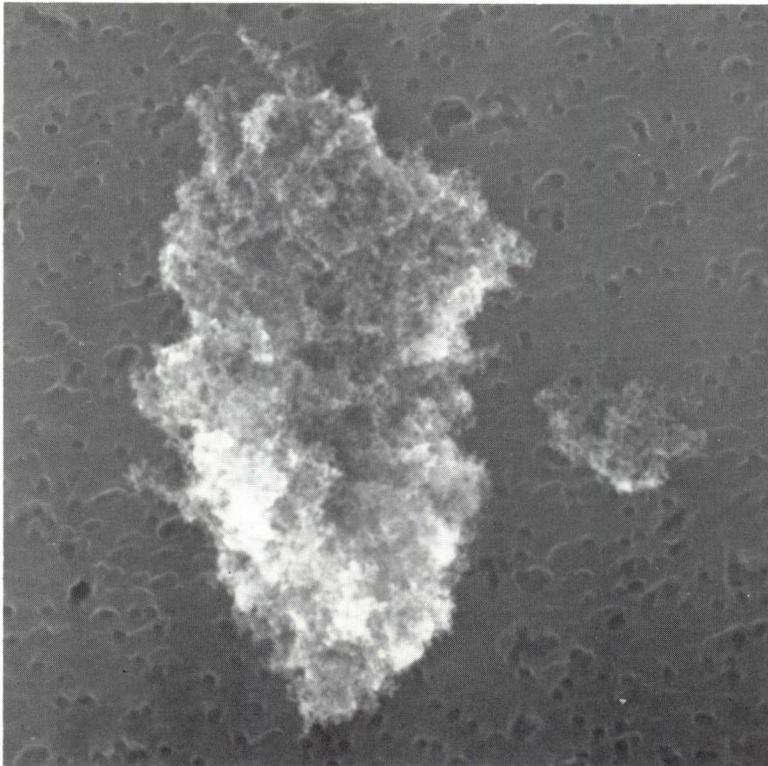


SIZE: 13
SHAPE: I
TRANS.: O
COLOR: Black to grey
LUSTER: D/SM
TYPE: ?
COMMENTS:

S-87-46016



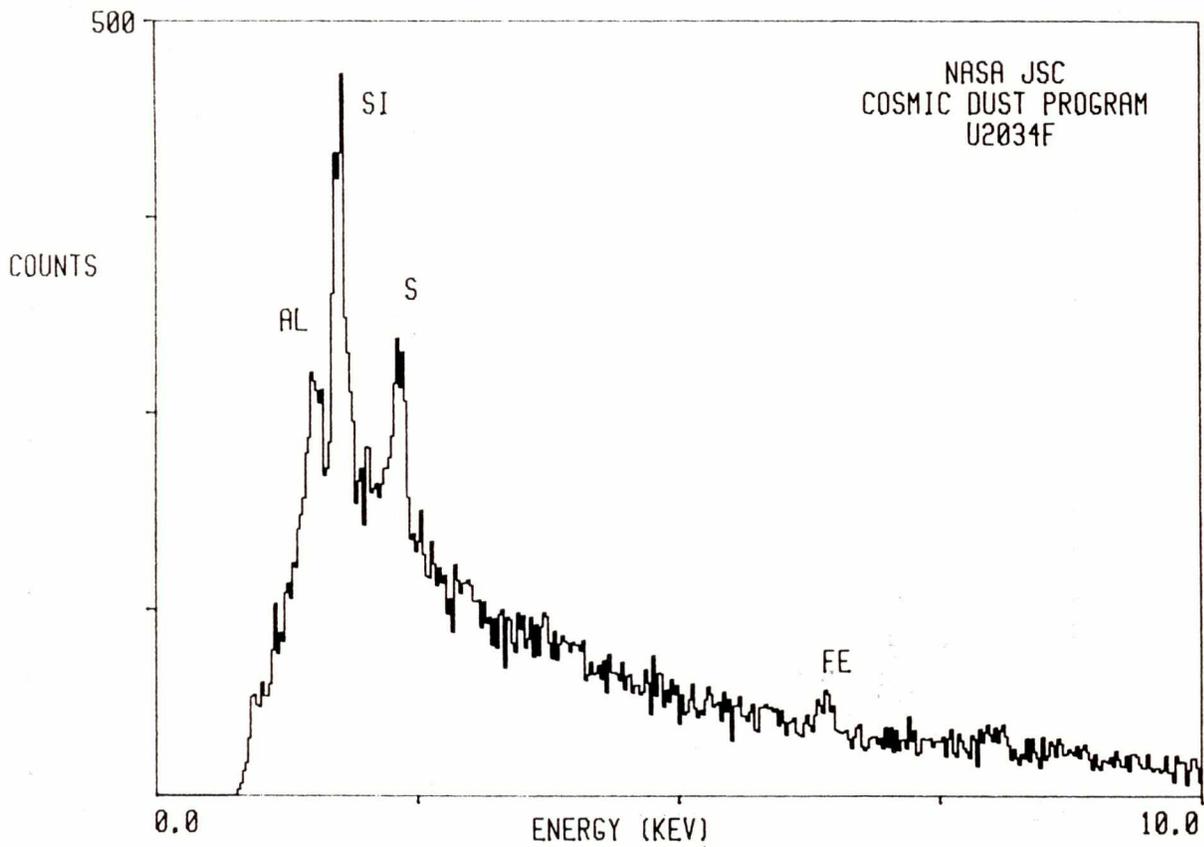
U2034 F 2



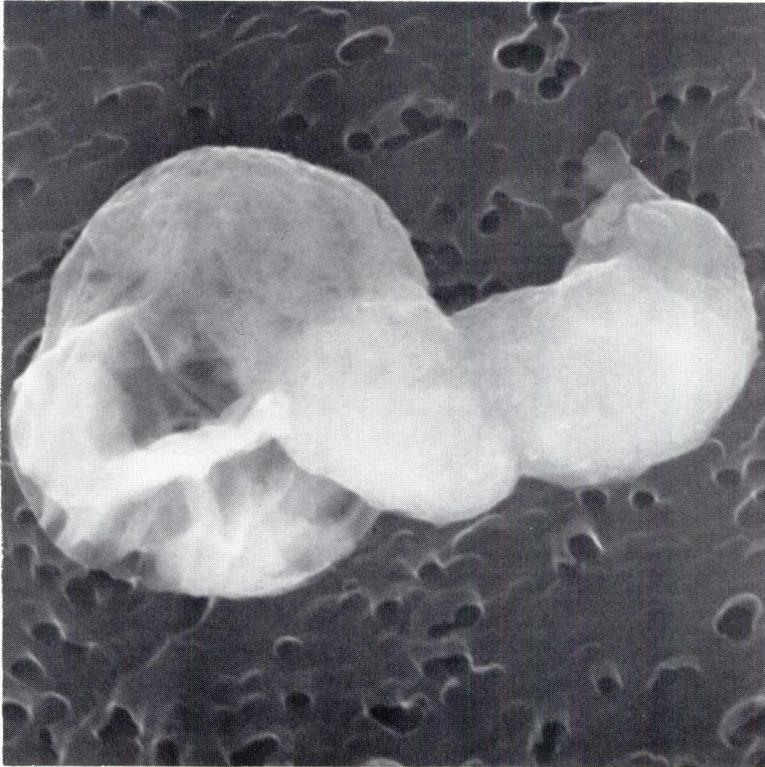
SIZE: 12x8
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: ?
COMMENTS:

S-87-46017

UF2

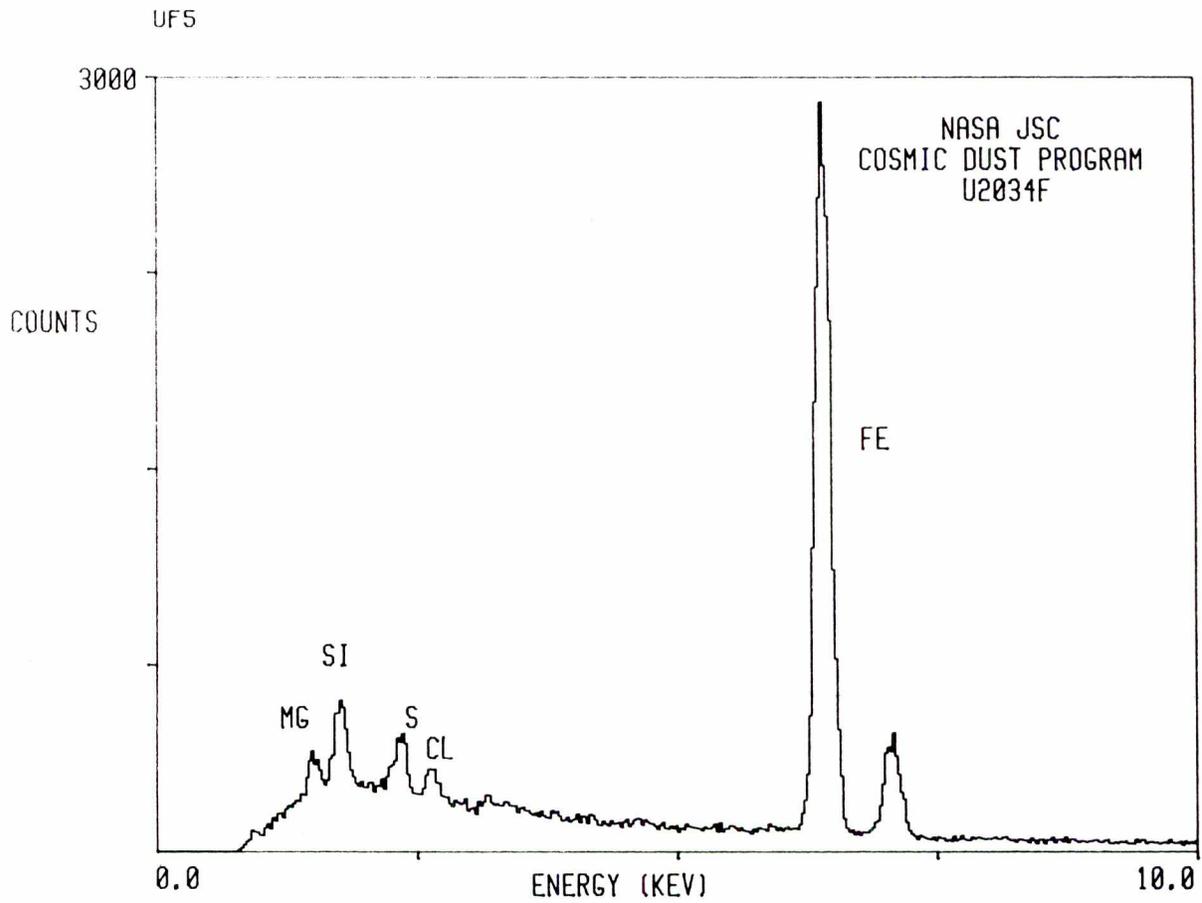


U2034 F 5

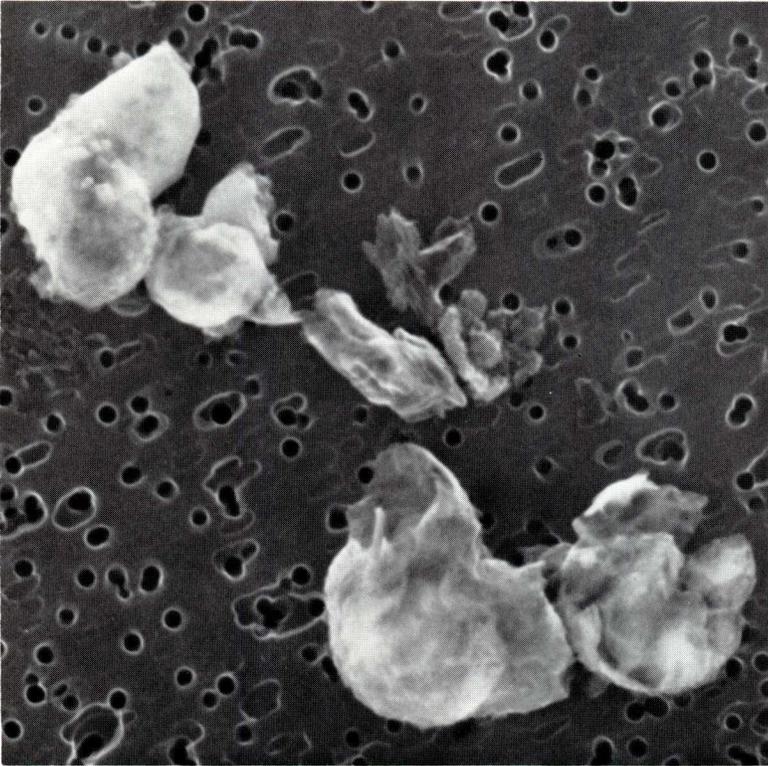


SIZE: 25x20
SHAPE: I
TRANS.: TL
COLOR: Yellow to white
LUSTER: D/SV
TYPE: ?
COMMENTS:

S-87-46018



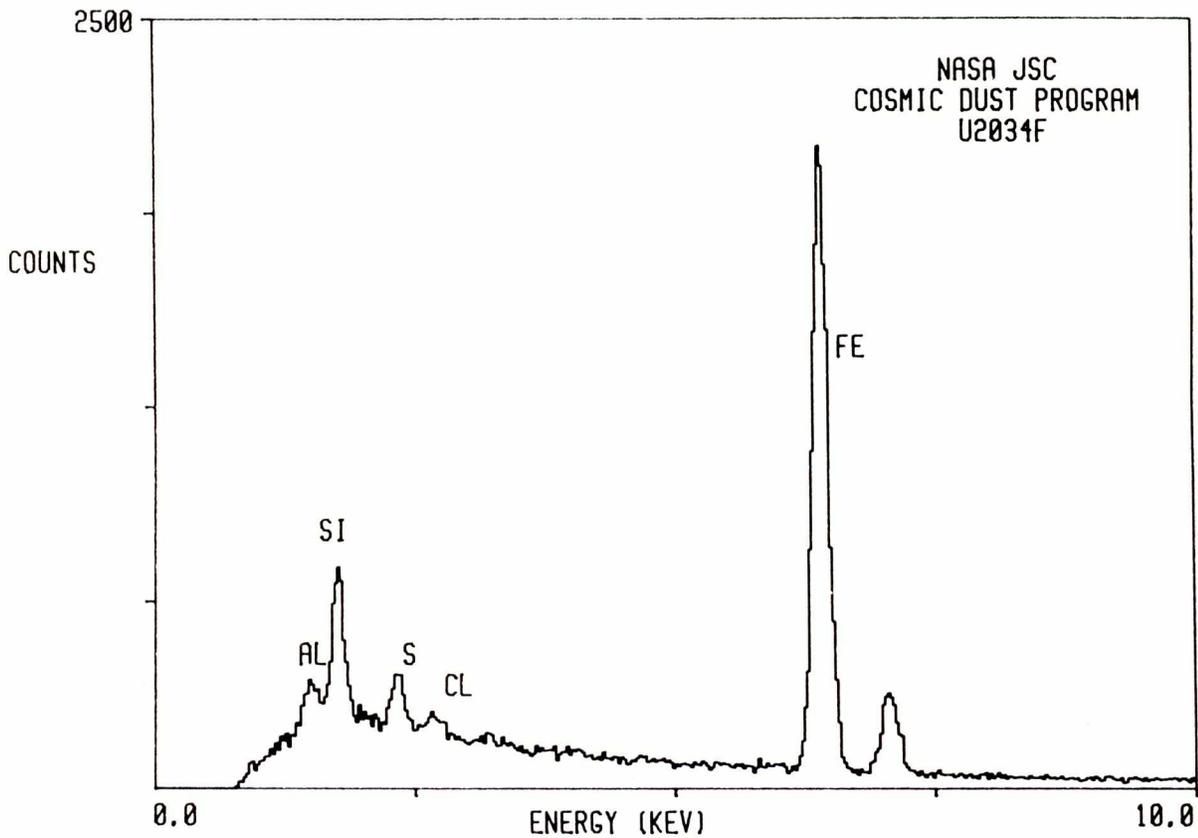
U2034 F 22



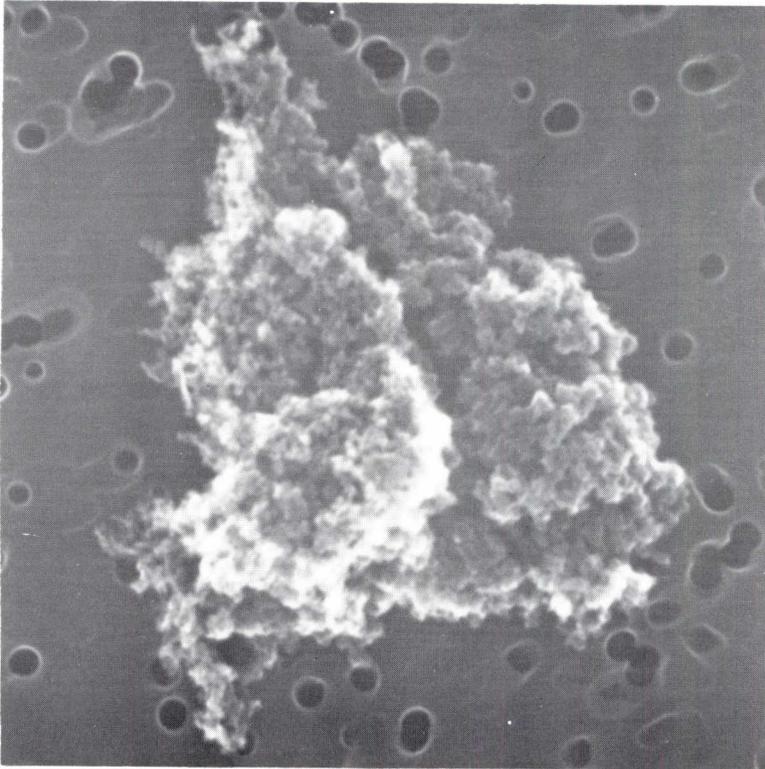
SIZE: 30x14
SHAPE: I
TRANS.: O/TL
COLOR: Black to reddish-brown
LUSTER: D/SV
TYPE: ?
COMMENTS:

S-87-46030

UF22

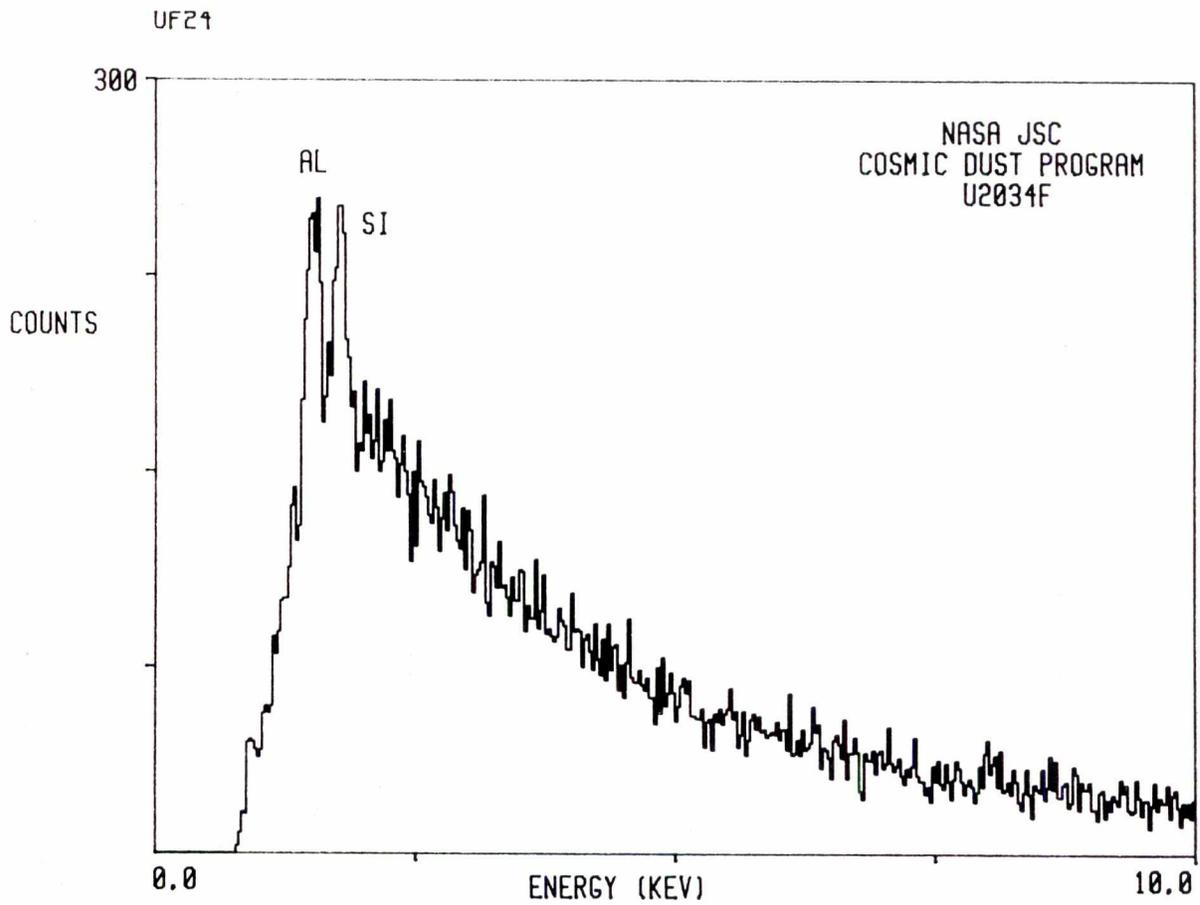


U2034 F 24

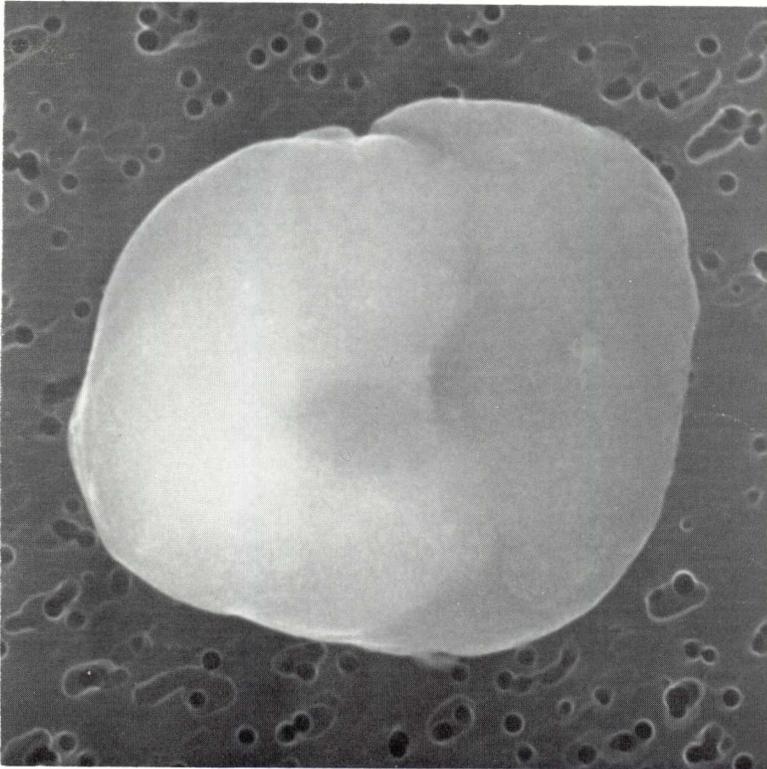


SIZE: 30x12
SHAPE: I
TRANS.: O/TL
COLOR: Black to reddish-brown
LUSTER: D/SV
TYPE: ?
COMMENTS:

S-87-46032

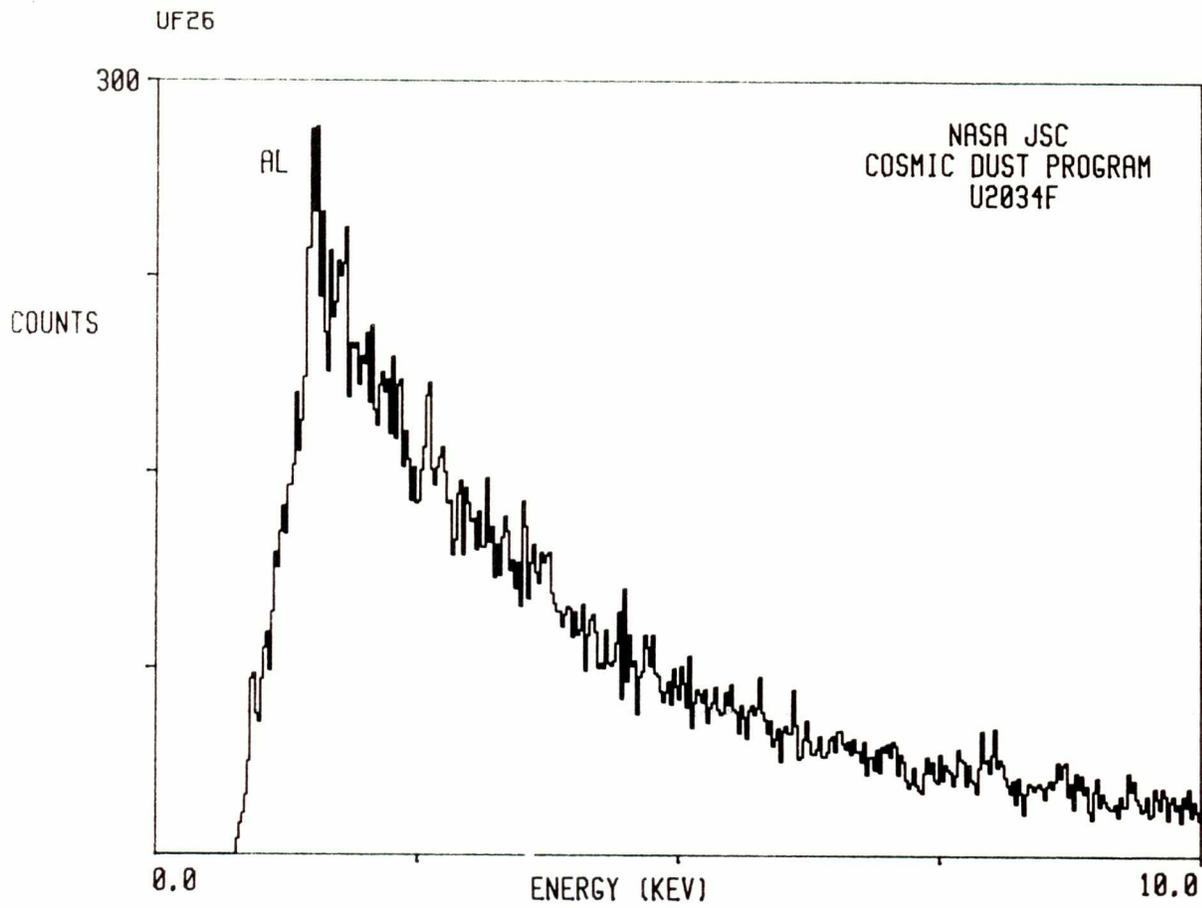


U2034 F 26



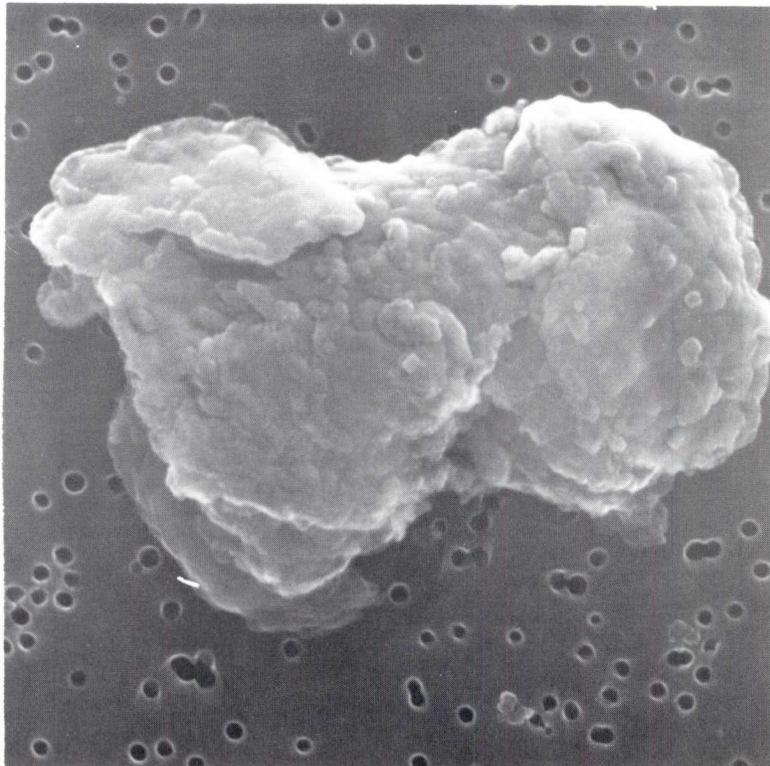
SIZE: 30x25
SHAPE: I
TRANS.: TL
COLOR: Yellow to white
LUSTER: D/SV
TYPE: ?
COMMENTS:

S-87-46034



TERRESTRIAL CONTAMINATION (ARTIFICIAL)

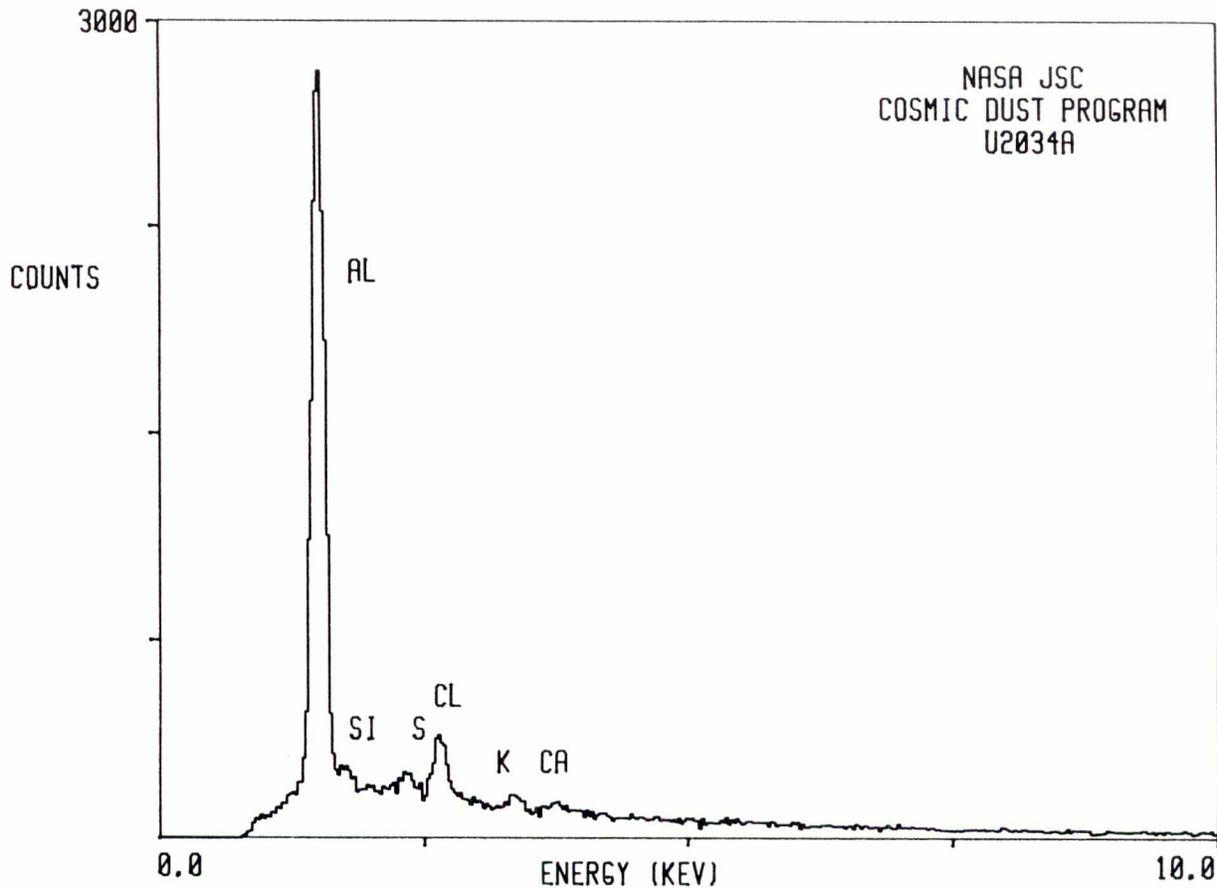
U2034 A 8



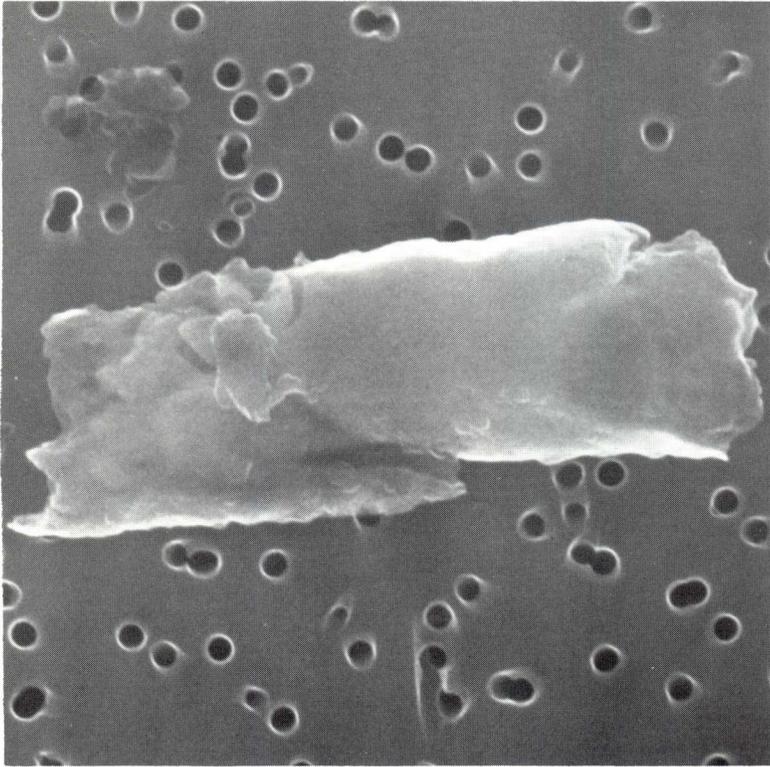
SIZE: 20x18
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: TCA
COMMENTS:

UAB

S-87-45929



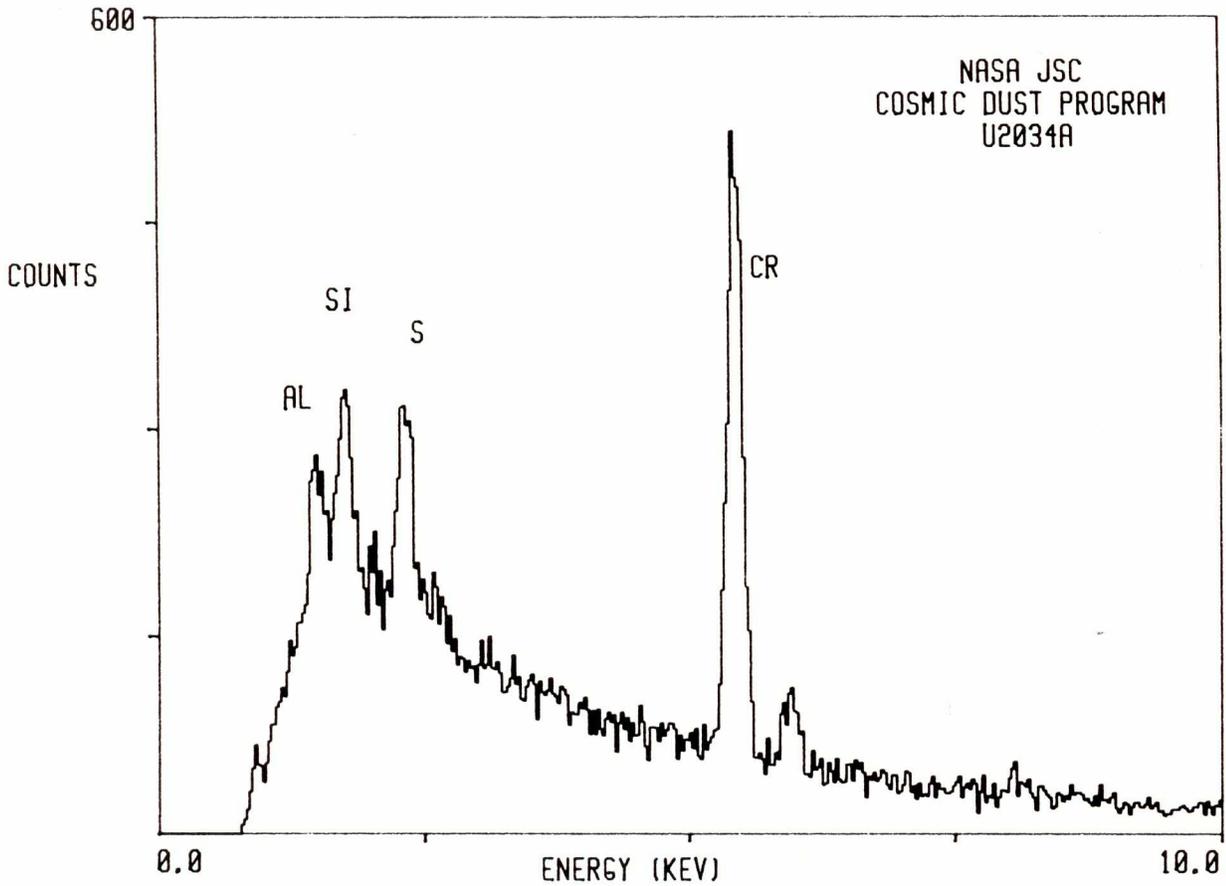
U2034 A 14



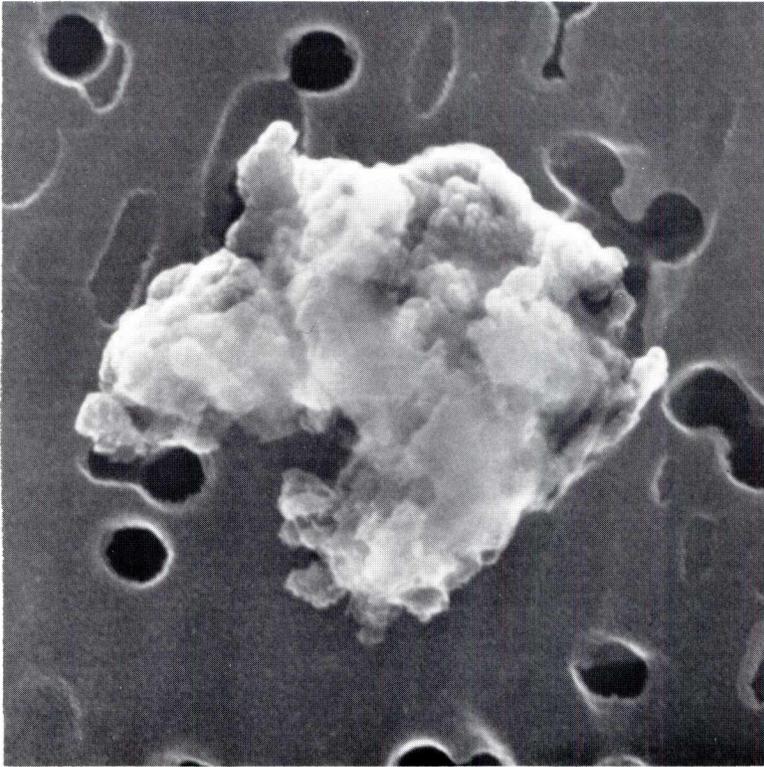
SIZE: 10x3
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D/SM
TYPE: TCA
COMMENTS:

UA14

S-87-45935



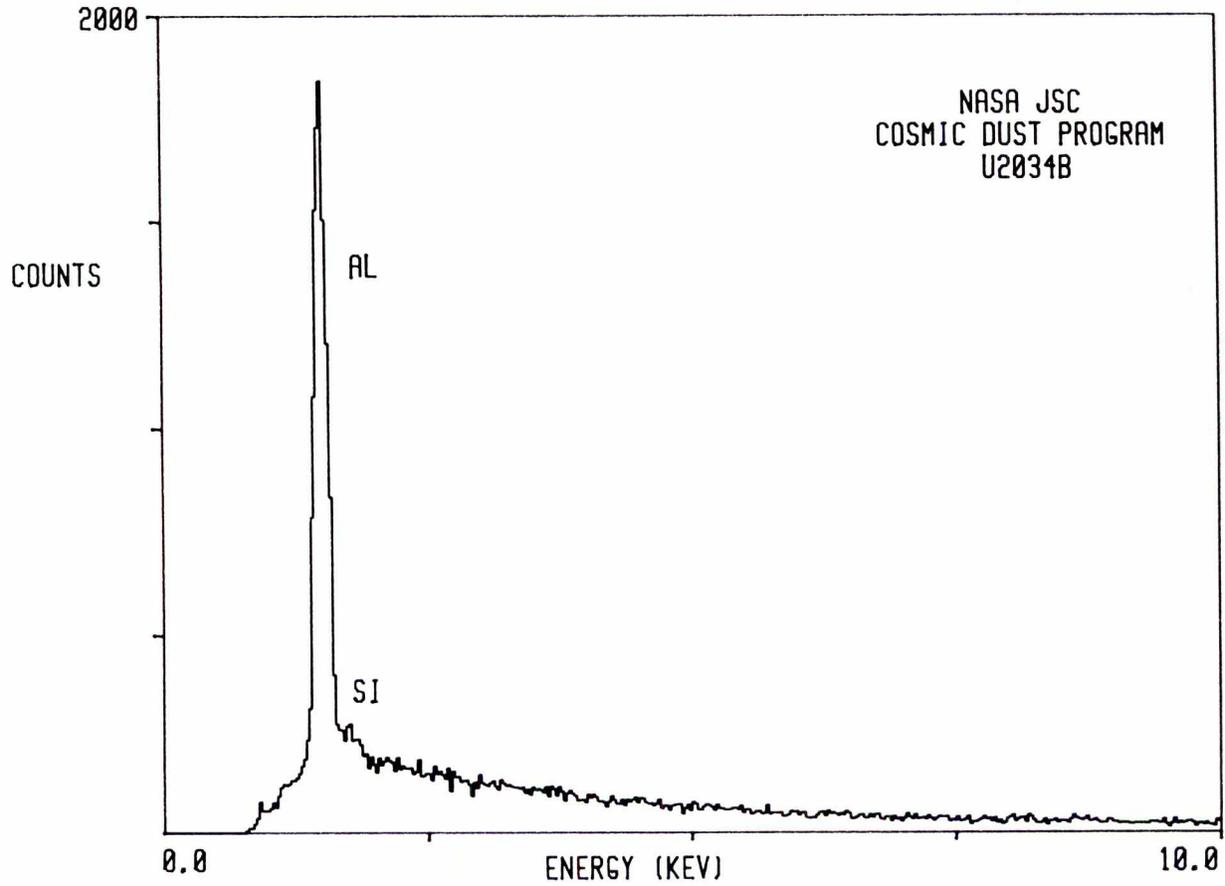
U2034 B 4



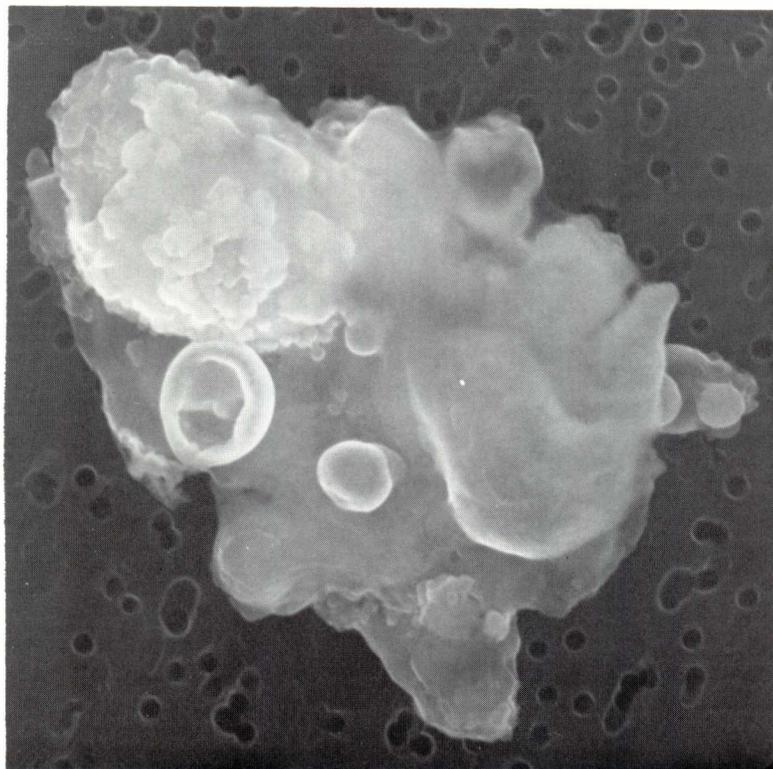
SIZE: 18x9
SHAPE: I
TRANS.: O
COLOR: Gold
LUSTER: SM
TYPE: TCA
COMMENTS:

UB4

S-87-45947

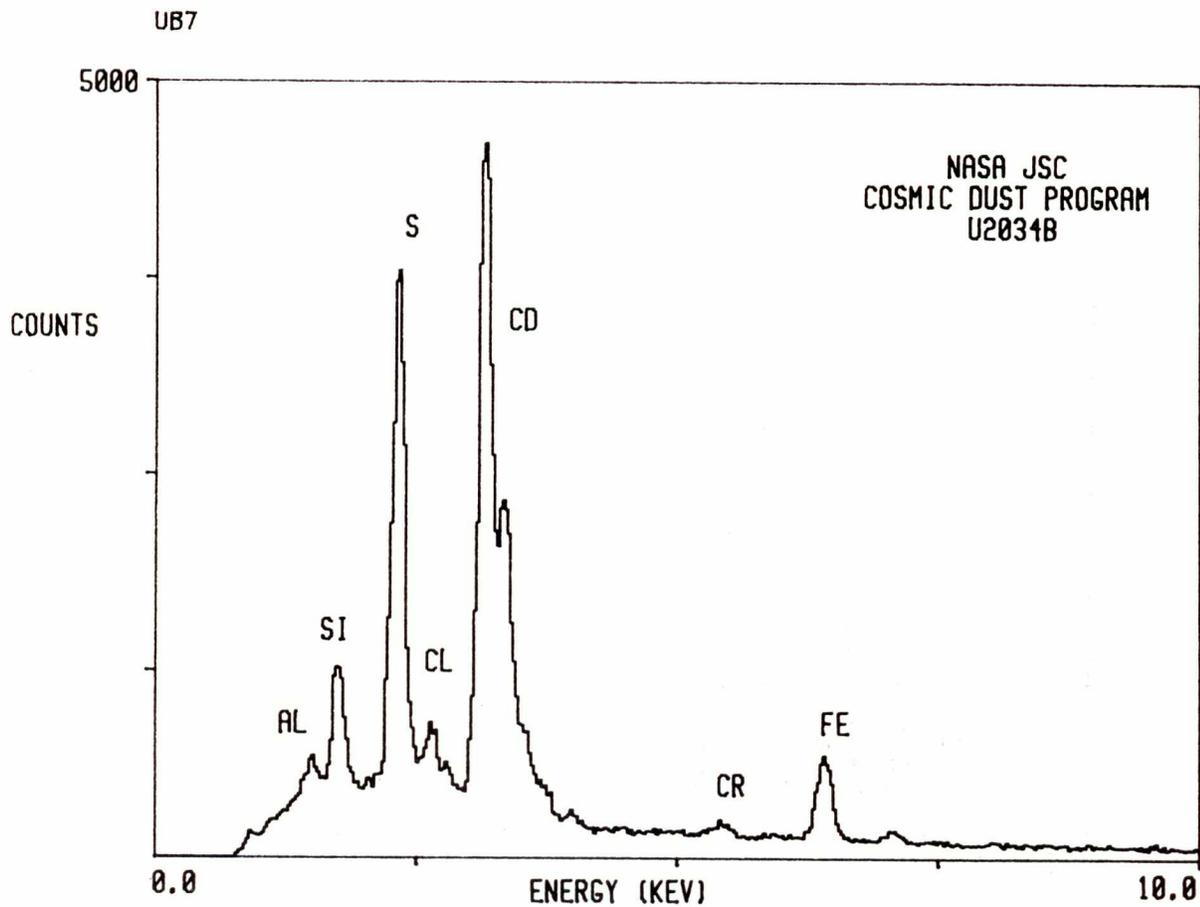


U2034 B 7

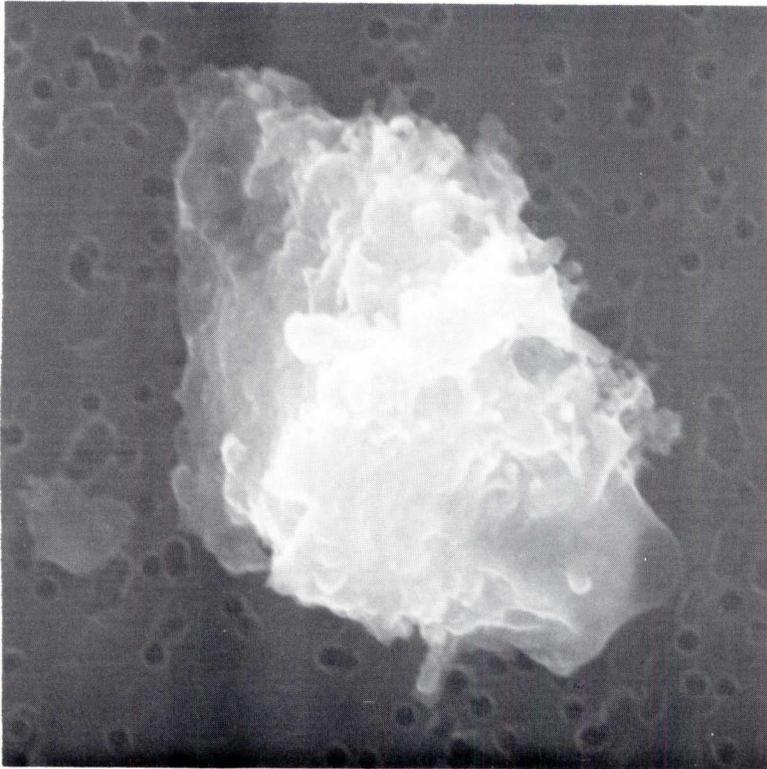


SIZE: 14x10
SHAPE: I
TRANS.: TL
COLOR: Yellow
LUSTER: D
TYPE: TCA
COMMENTS:

S-87-45950



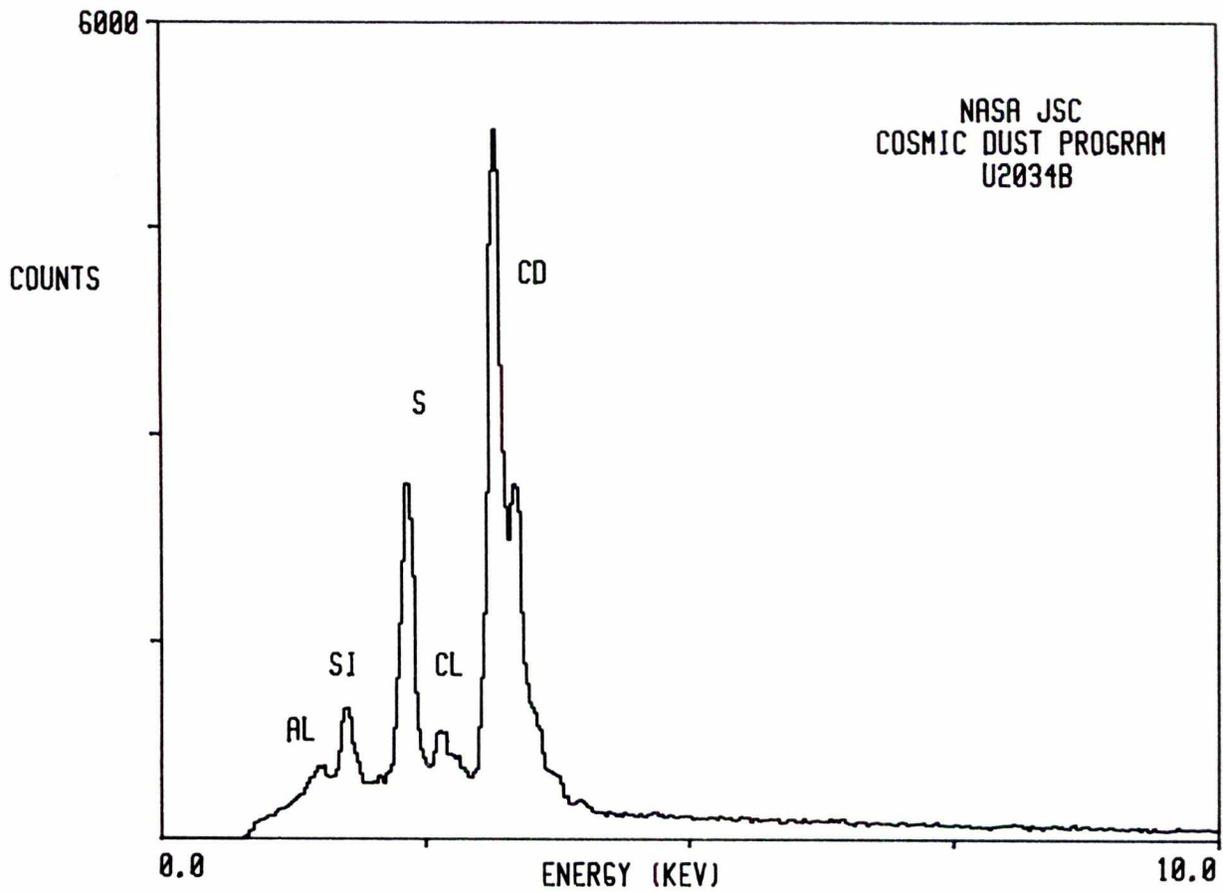
U2034 B 13



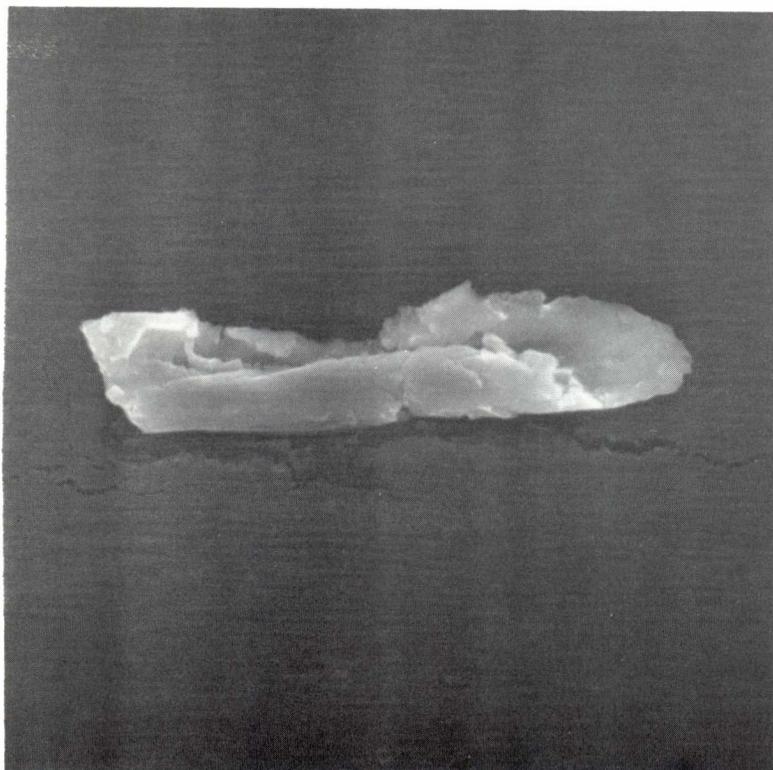
SIZE: 10
SHAPE: I
TRANS.: TL
COLOR: Yellow
LUSTER: SV
TYPE: TCA
COMMENTS:

UB13

S-87-45956



U2034 D 3



SIZE: 100x20

SHAPE: I

TRANS.: O

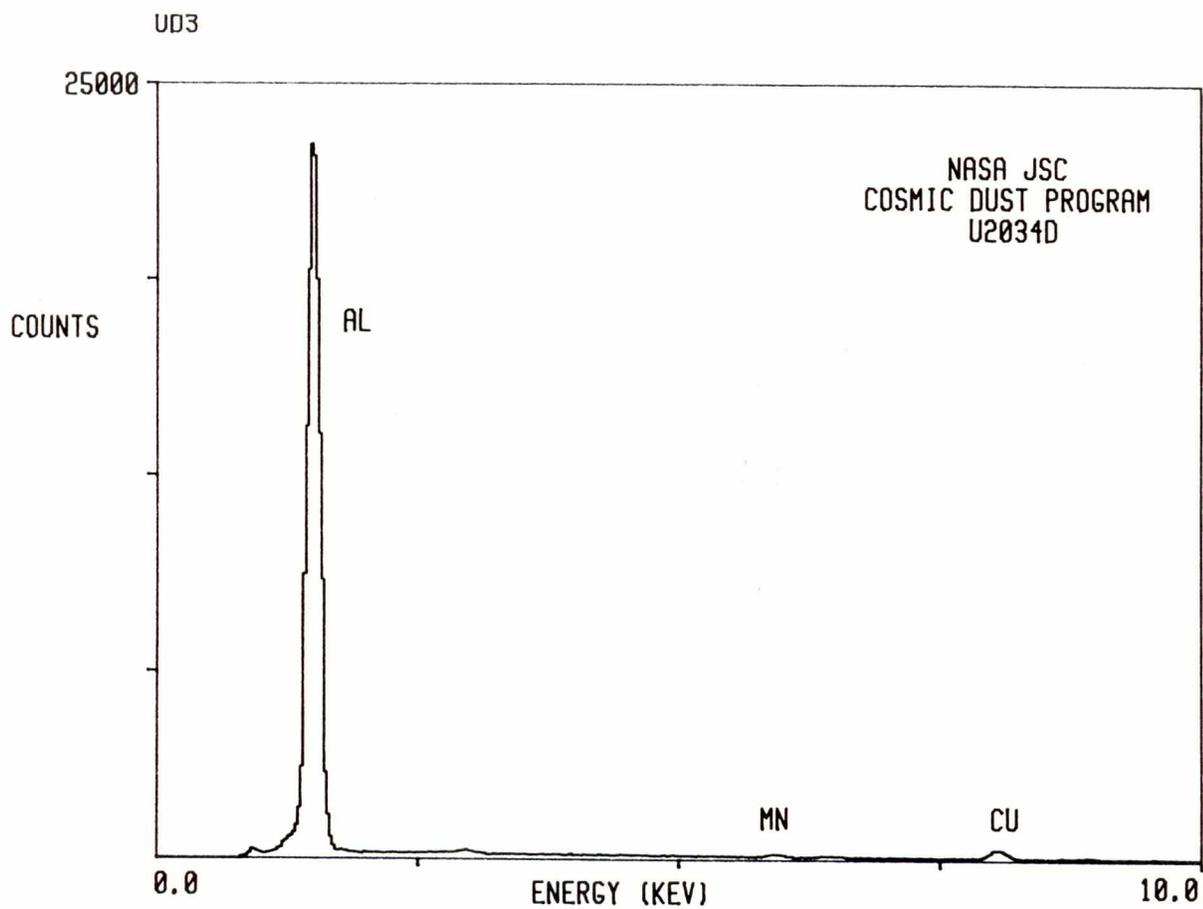
COLOR: Gold

LUSTER: M

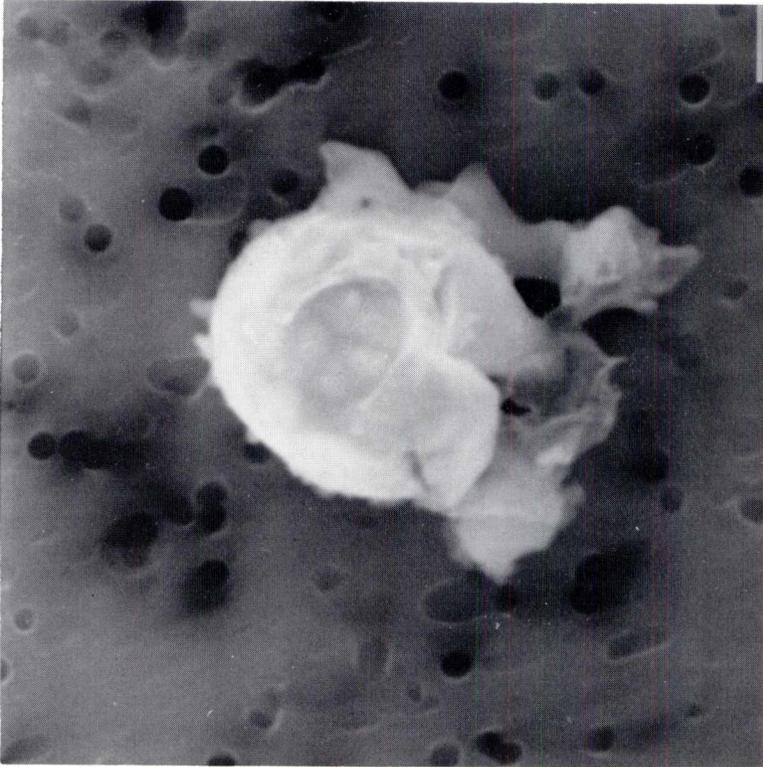
TYPE: TCA

COMMENTS:

S-87-45982

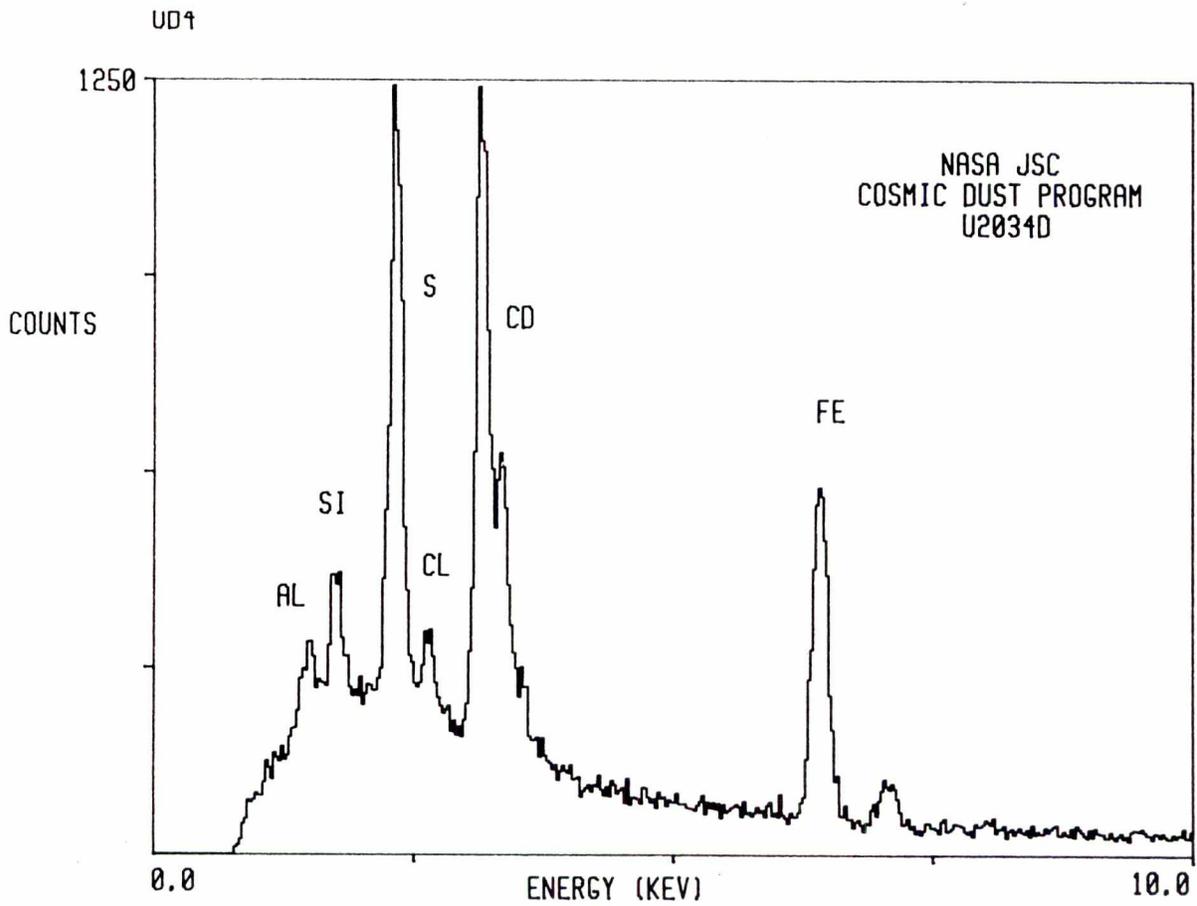


U2034 D 4

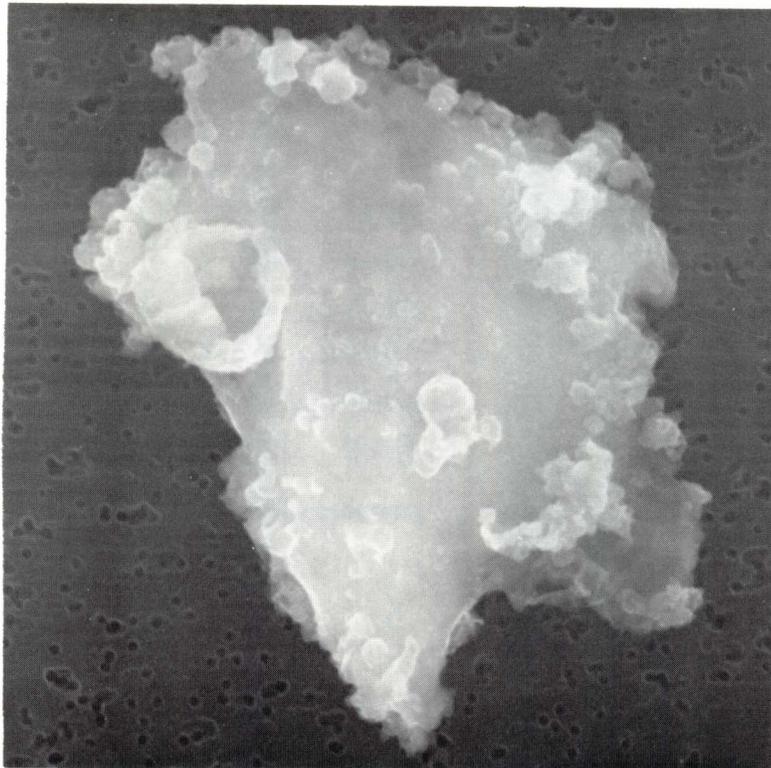


SIZE: 30x15
SHAPE: I
TRANS.: O/TL
COLOR: Black to red-brown
LUSTER: D/SV
TYPE: TCA
COMMENTS:

S-87-45996

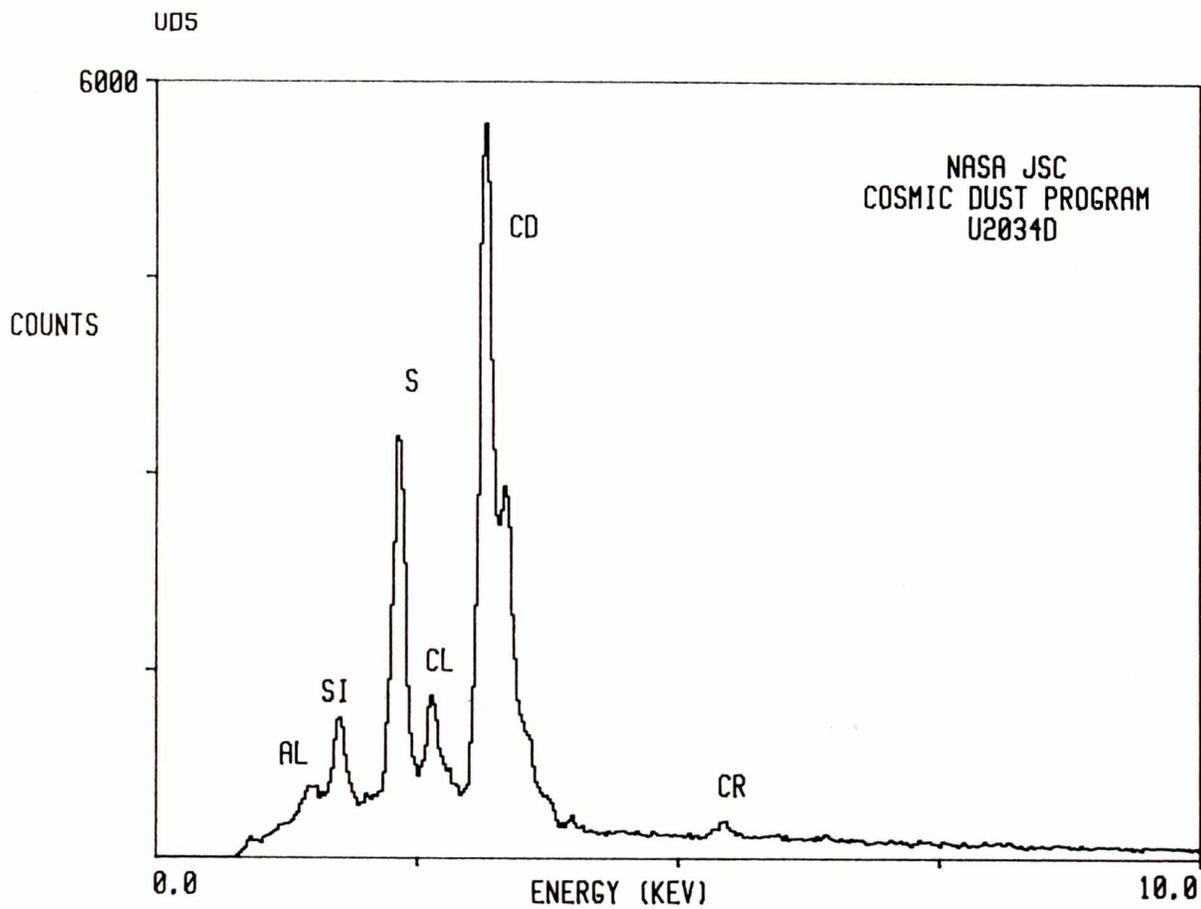


U2034 D 5

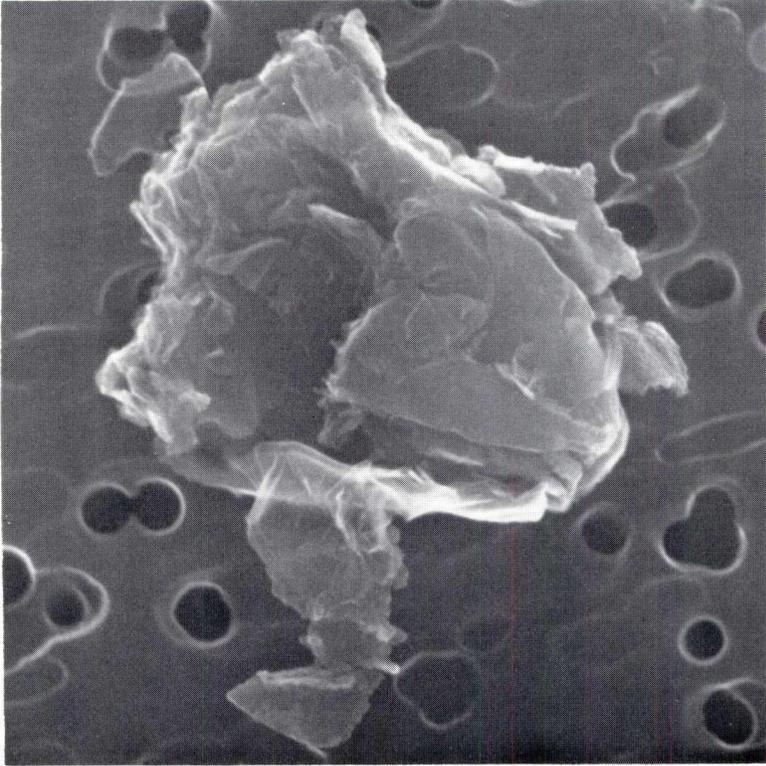


SIZE: 20
SHAPE: I
TRANS.: TL
COLOR: Yellow to white
LUSTER: D/SV
TYPE: TCA
COMMENTS:

S-87-45983

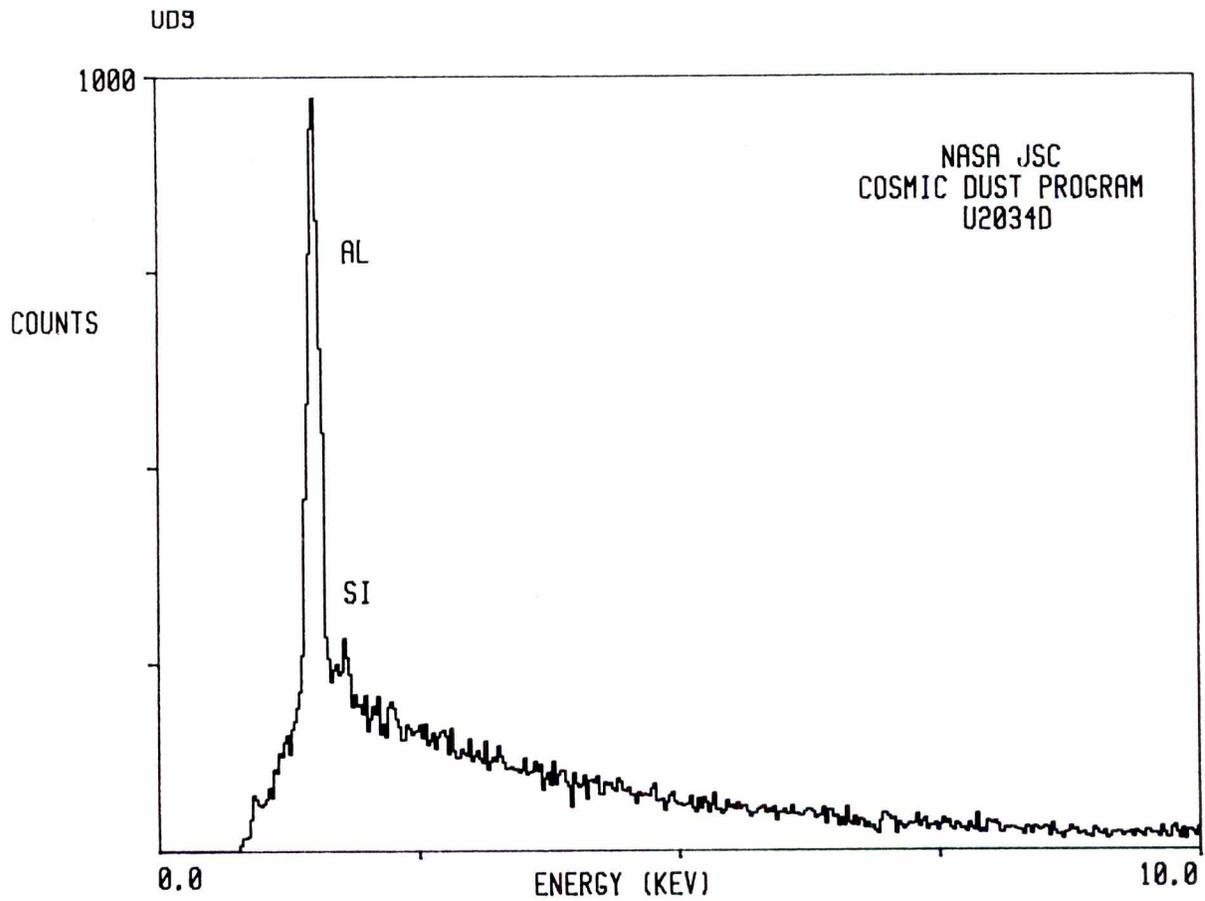


U2034 D 9

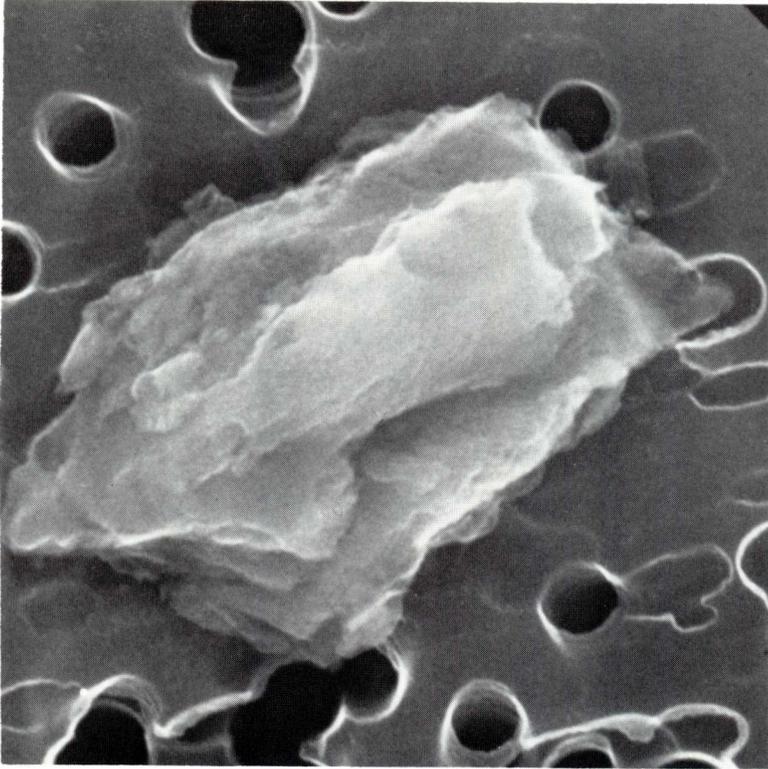


SIZE: 5x3
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: TCA
COMMENTS:

S-87-45987

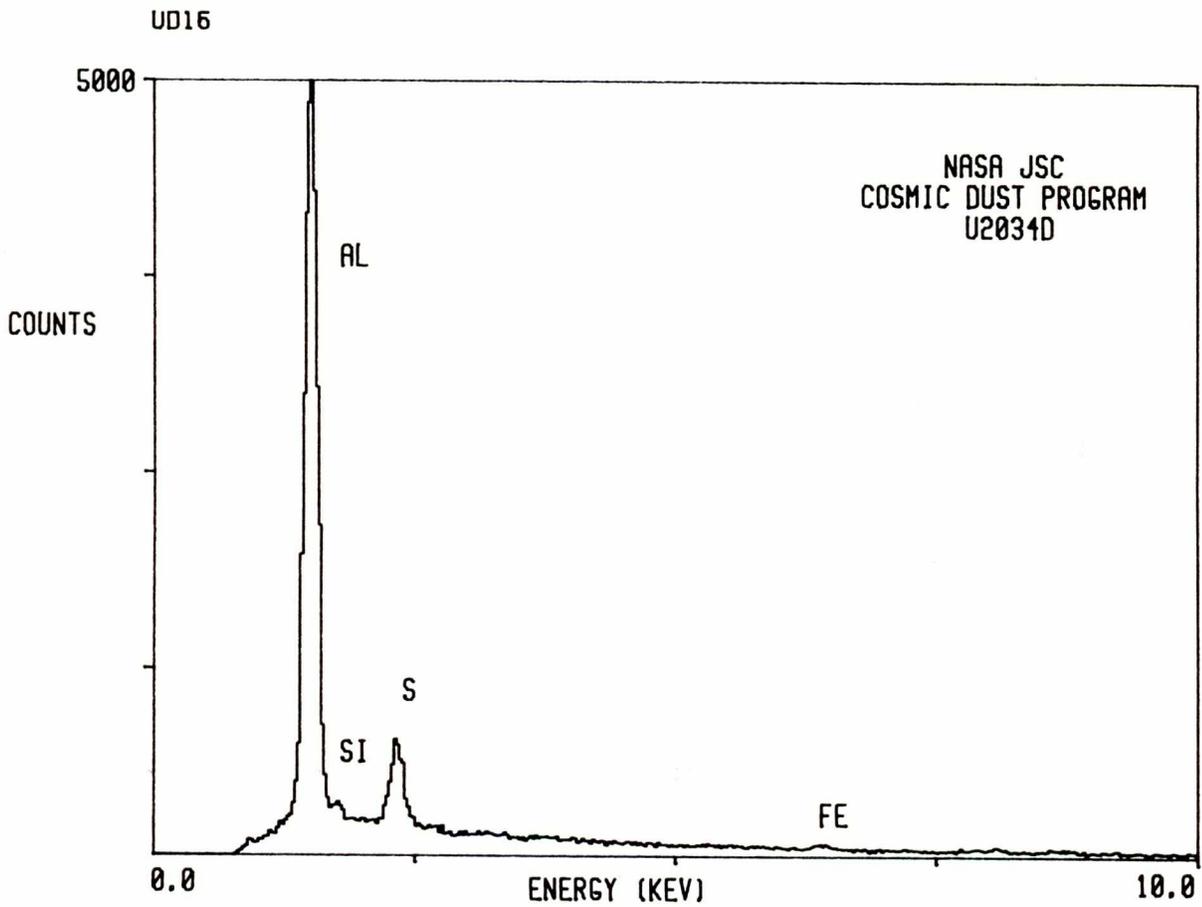


U2034 D 16

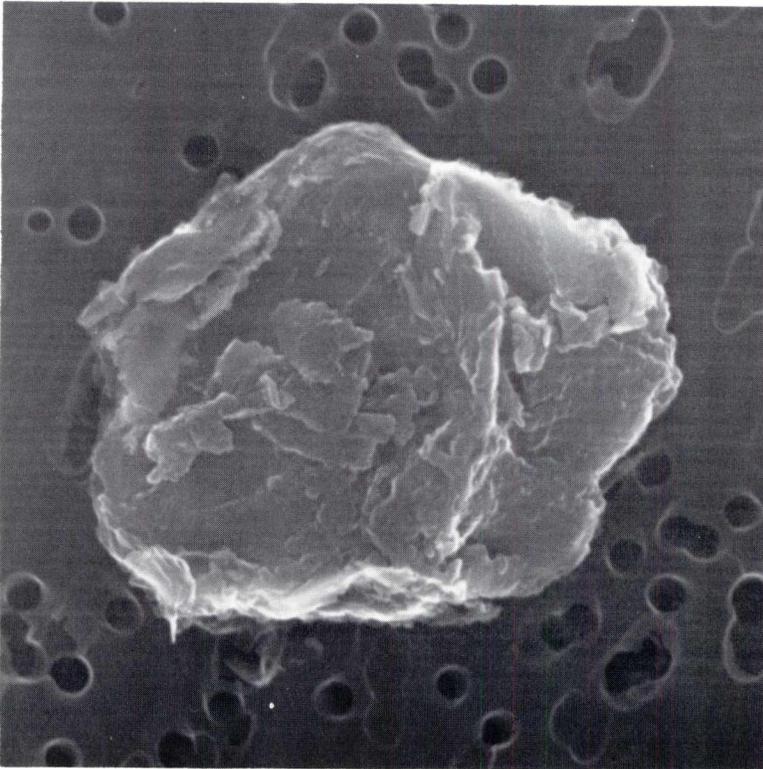


SIZE: 20
SHAPE: I
TRANS.: O
COLOR: Gold
LUSTER: M
TYPE: TCA
COMMENTS:

S-87-45993

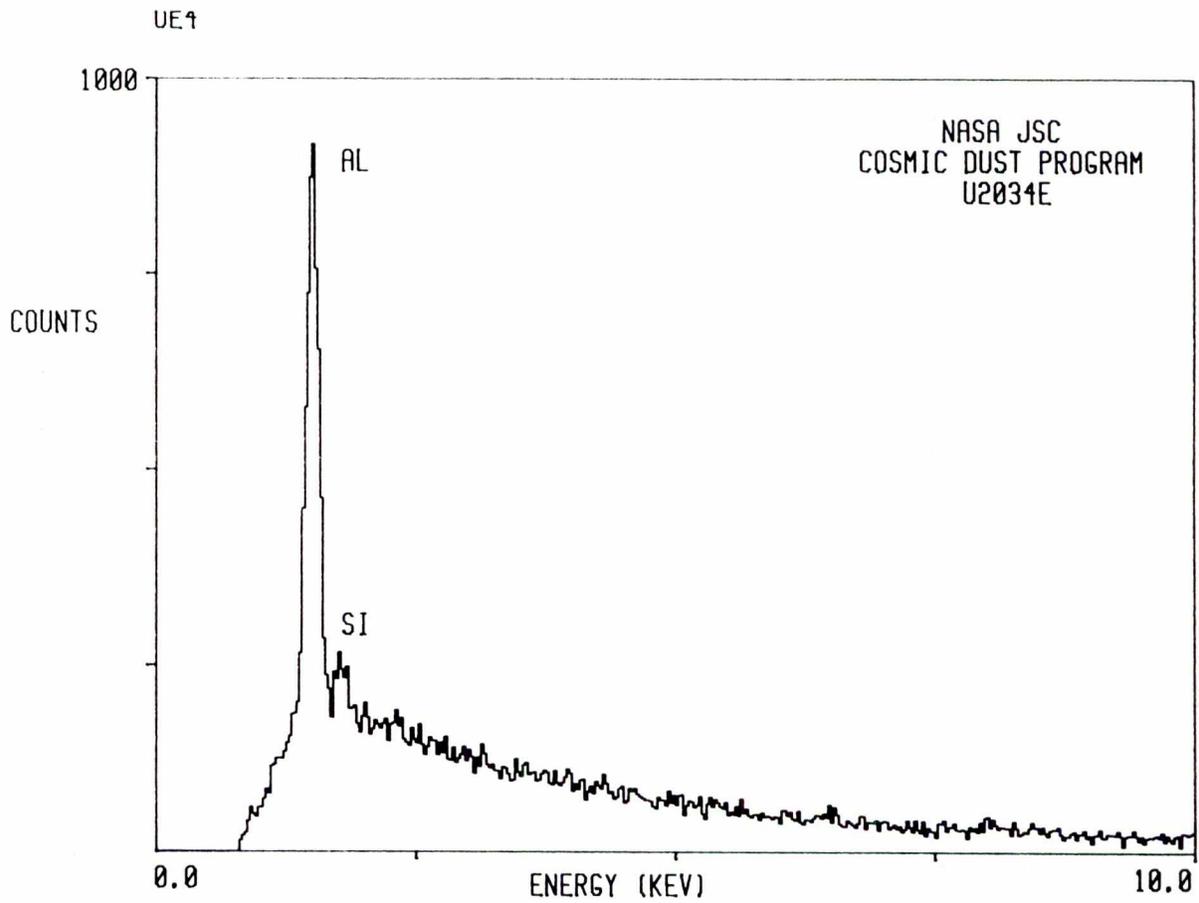


U2034 E 4

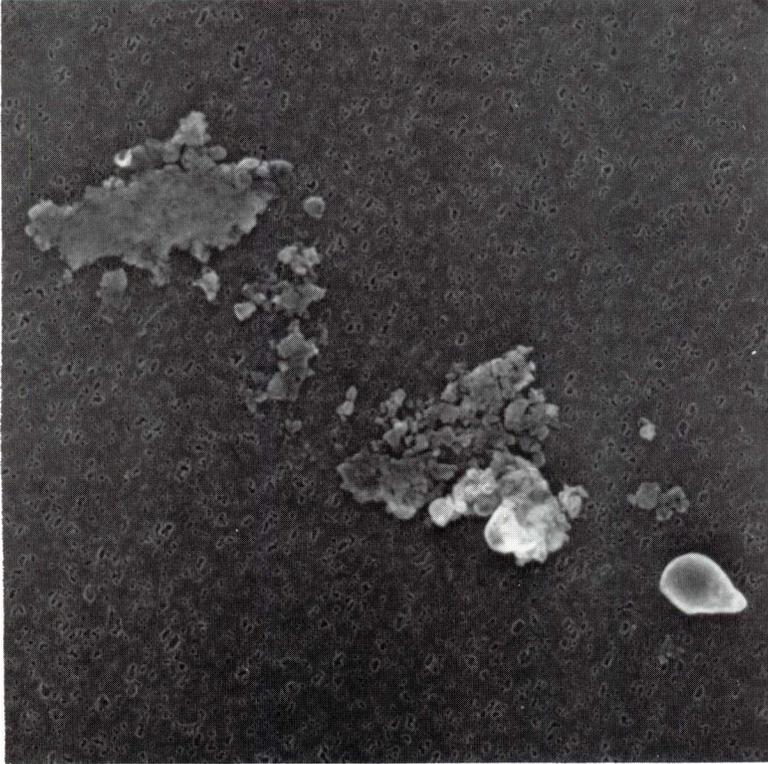


SIZE: 14x10
SHAPE: I
TRANS.: TL
COLOR: Red to yellow
LUSTER: SV
TYPE: TCA
COMMENTS:

S-87-46000

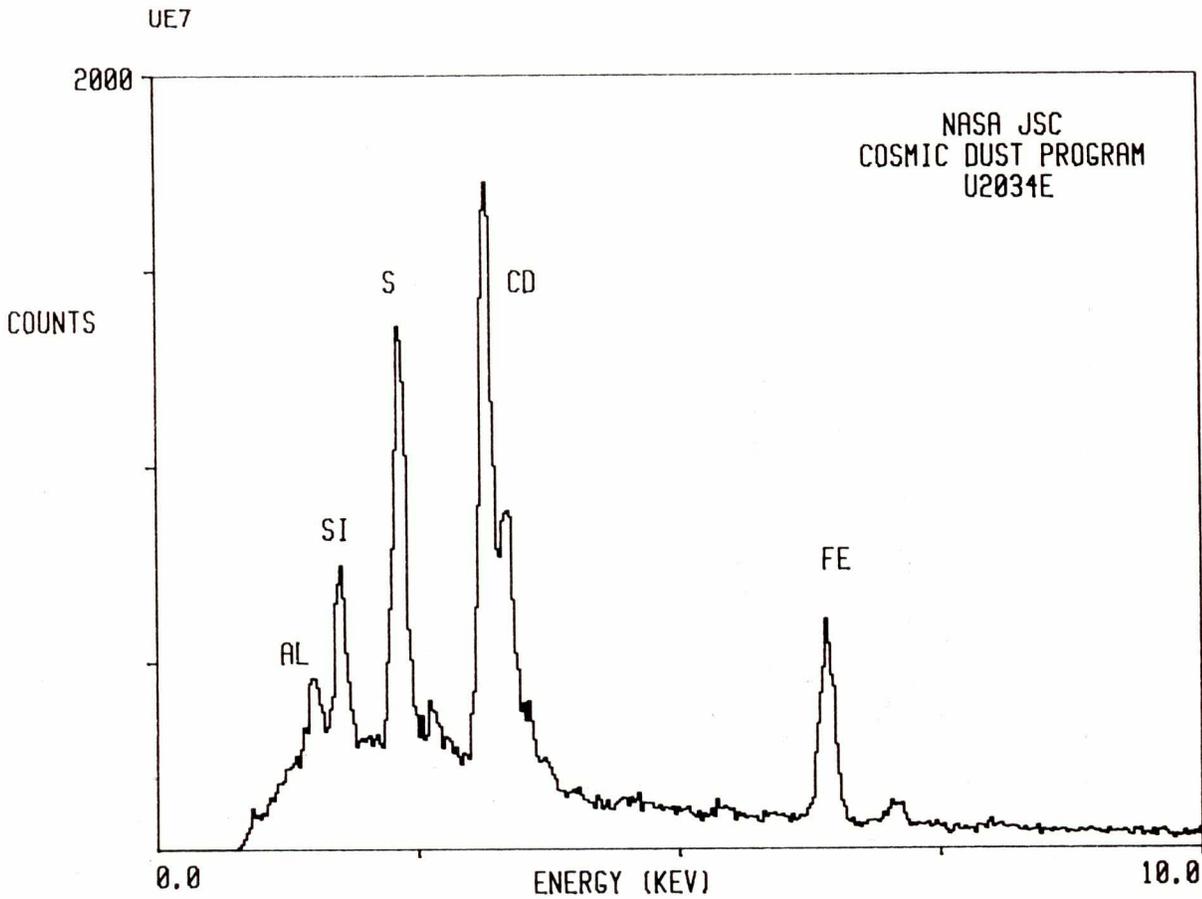


U2034 E 7

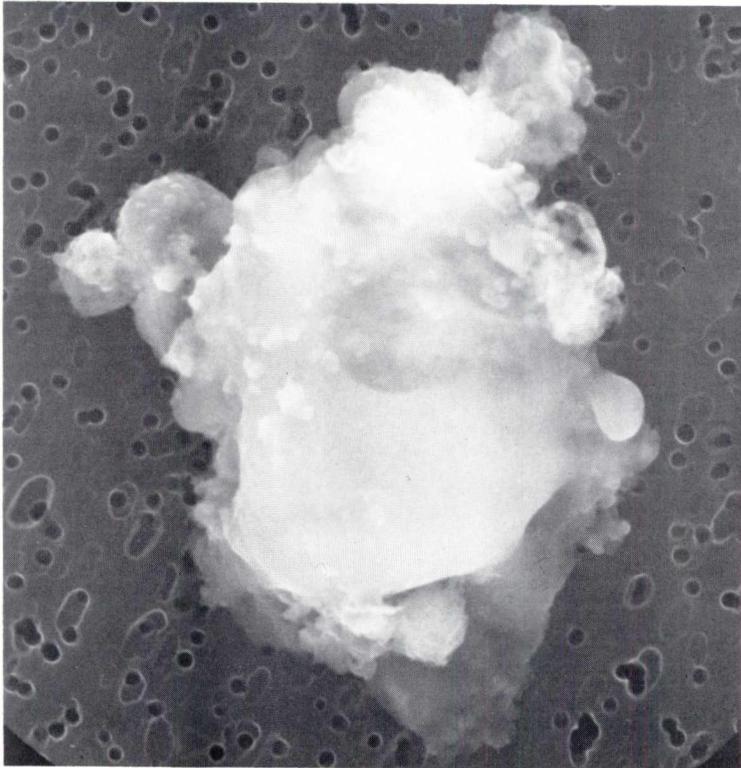


SIZE: 60x40
SHAPE: I
TRANS.: TL
COLOR: Yellow
LUSTER: D
TYPE: TCA
COMMENTS:
Field of particles

S-87-46003

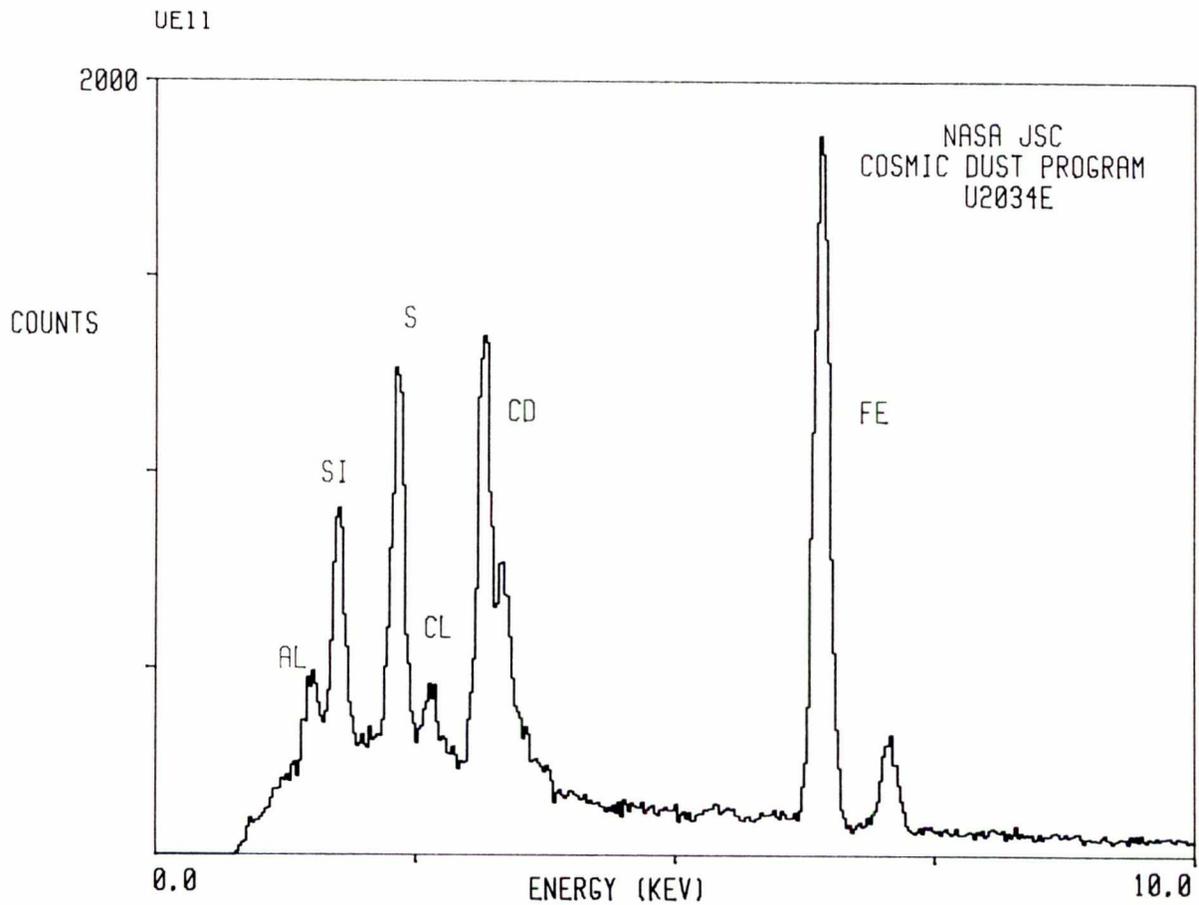


U2034 E 11

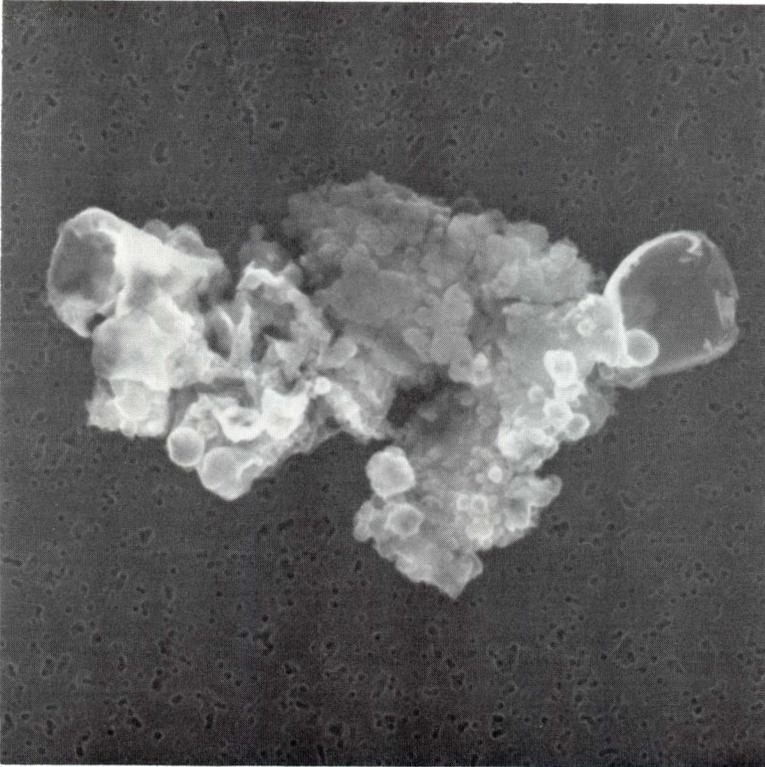


SIZE: 11
SHAPE: I
TRANS.: O/TL
COLOR: Reddish-brown
LUSTER: SV
TYPE: TCA
COMMENTS:

S-87-46007

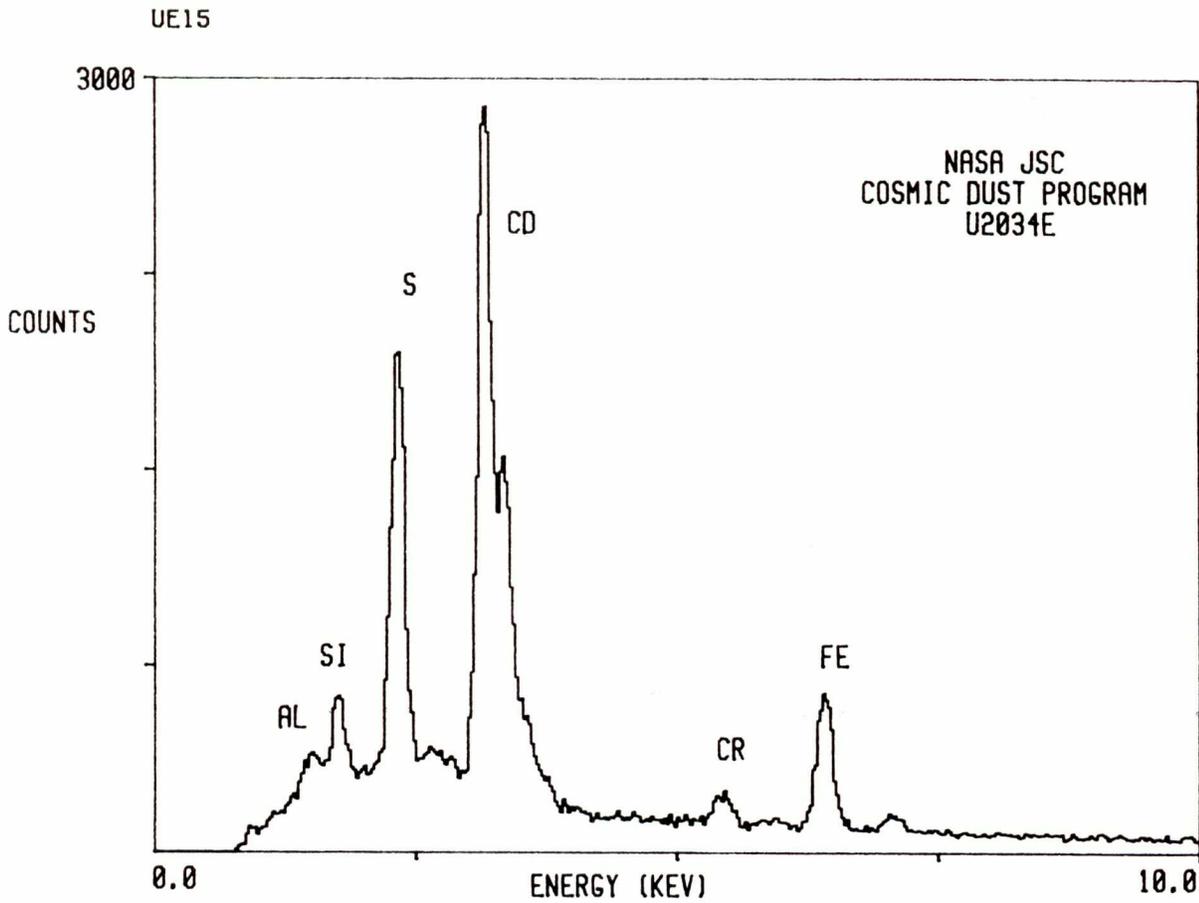


U2034 E 15

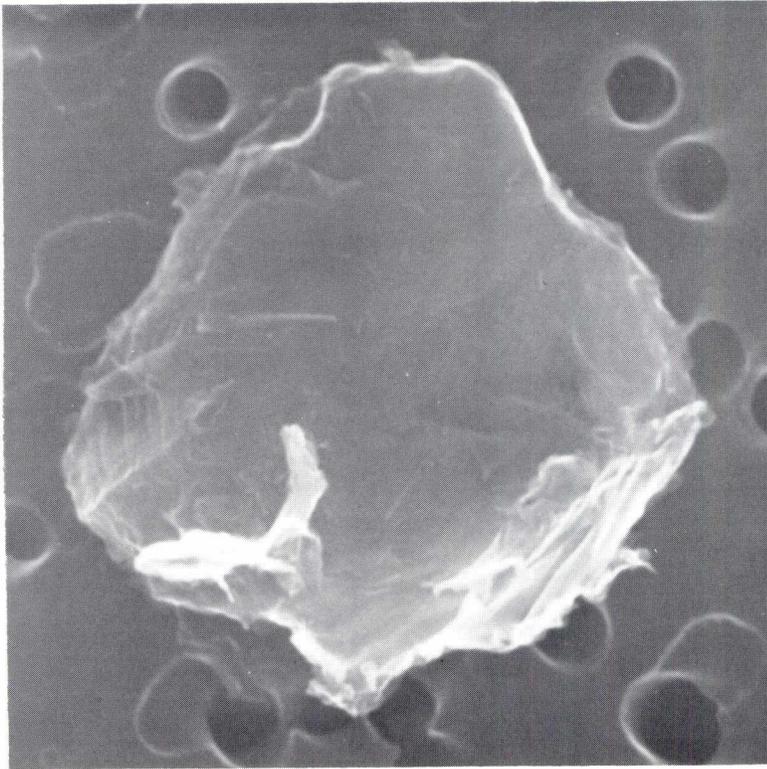


SIZE: 25x20
SHAPE: I
TRANS.: TL
COLOR: Reddish-brown
to yellow
LUSTER: D/SV
TYPE: TCA
COMMENTS:

S-87-46010

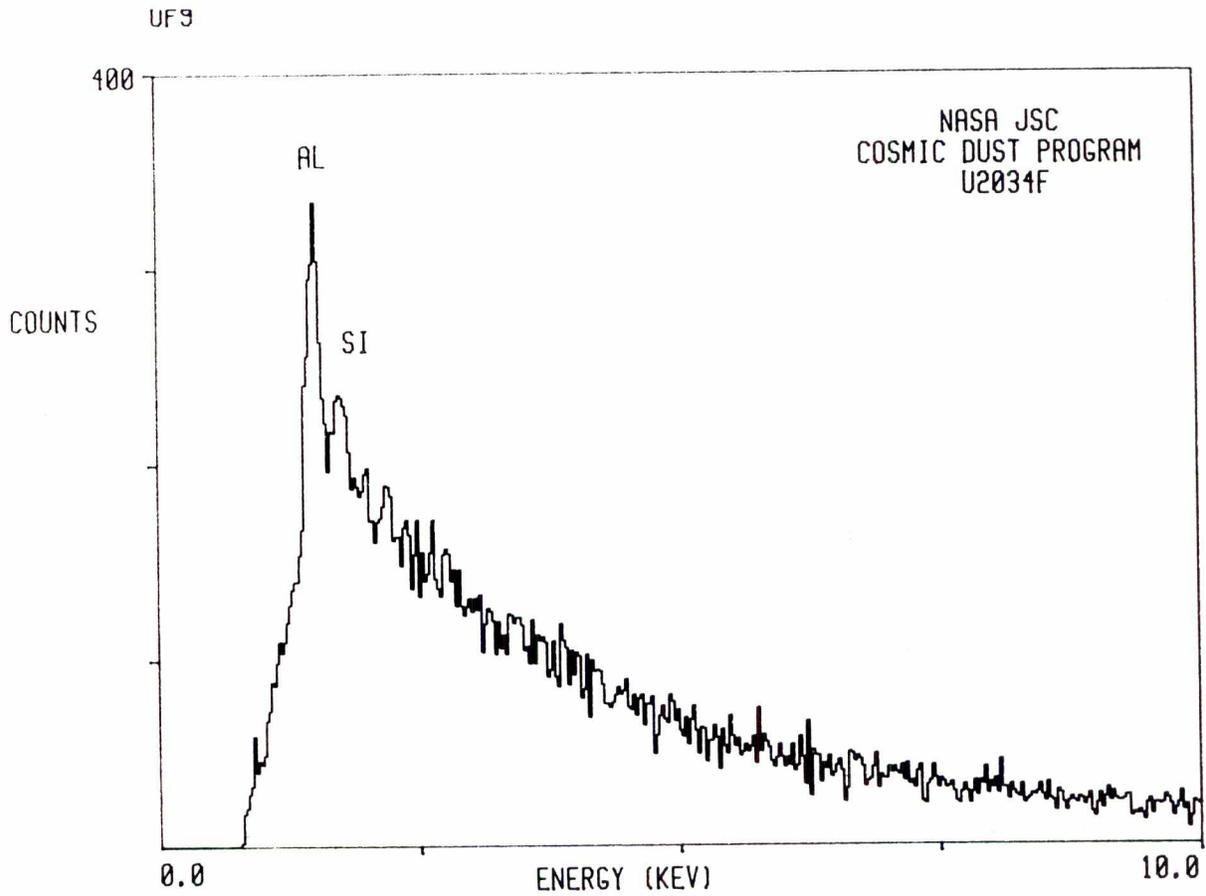


U2034 F 9

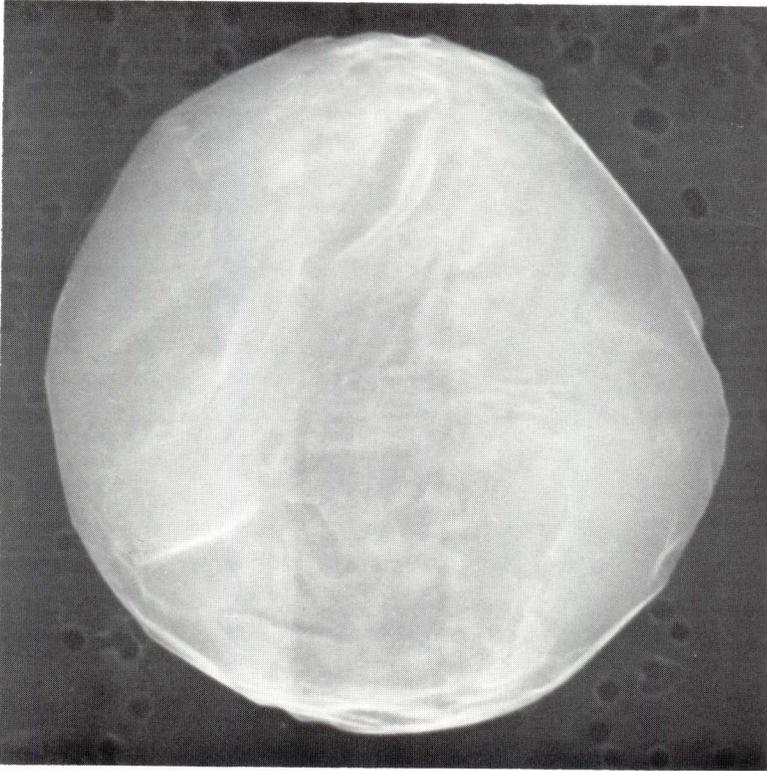


SIZE: 20x18
SHAPE: S/I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCA
COMMENTS:

S-87-46021



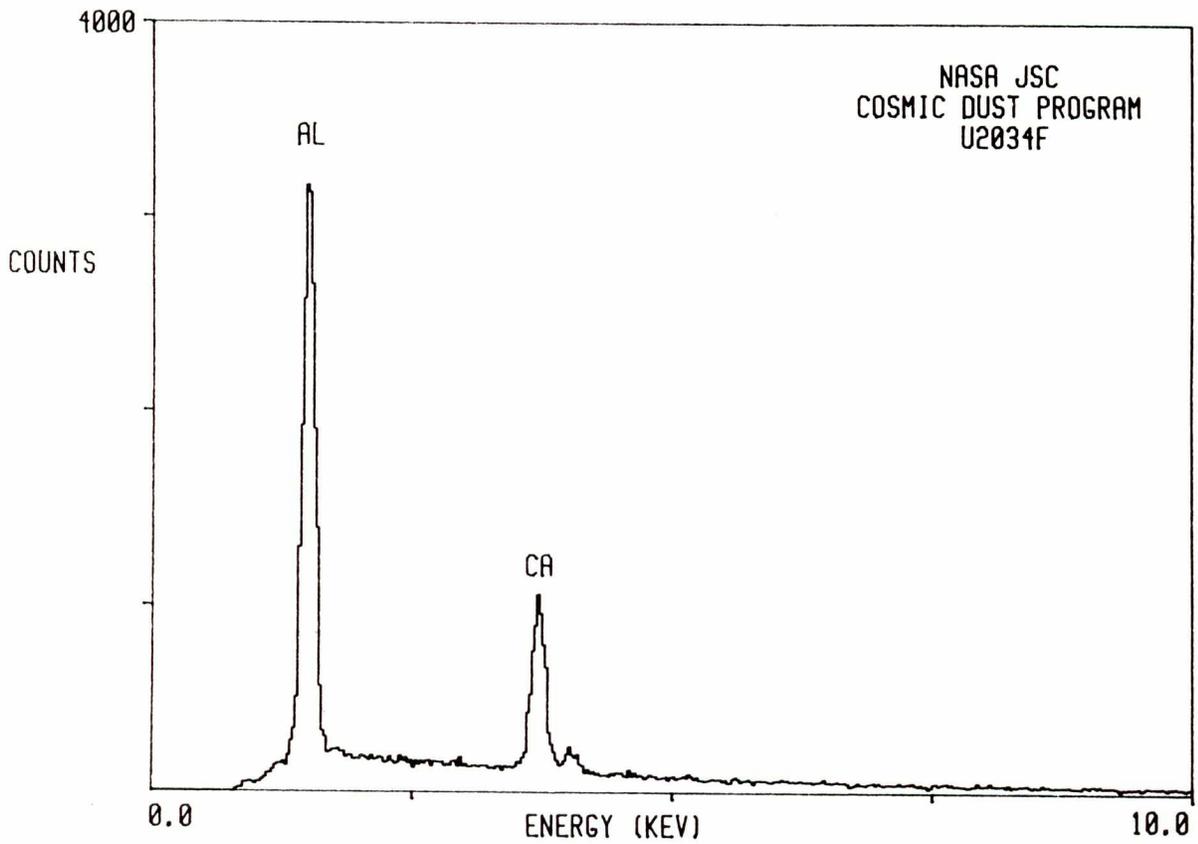
U2034 F 12



SIZE: 10
SHAPE: S
TRANS.: T
COLOR: Yellow
LUSTER: V
TYPE: TCA
COMMENTS:

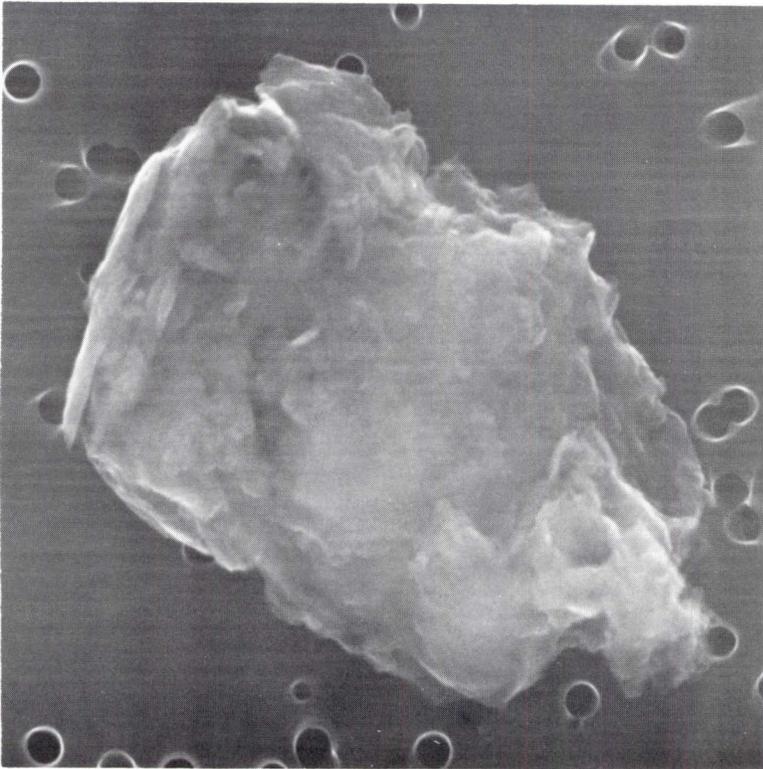
S-87-46024

UF12



TERRESTRIAL CONTAMINATION (NATURAL)

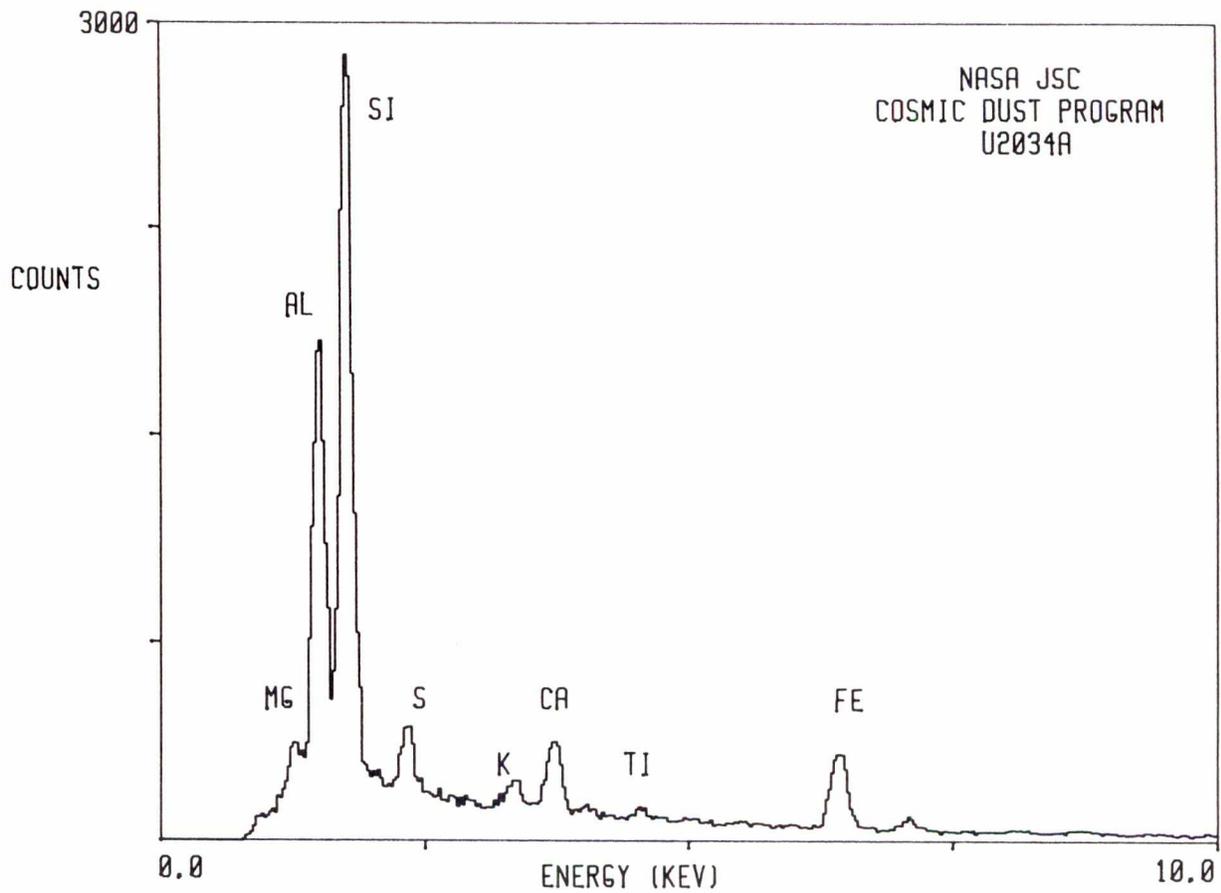
U2034 A 1



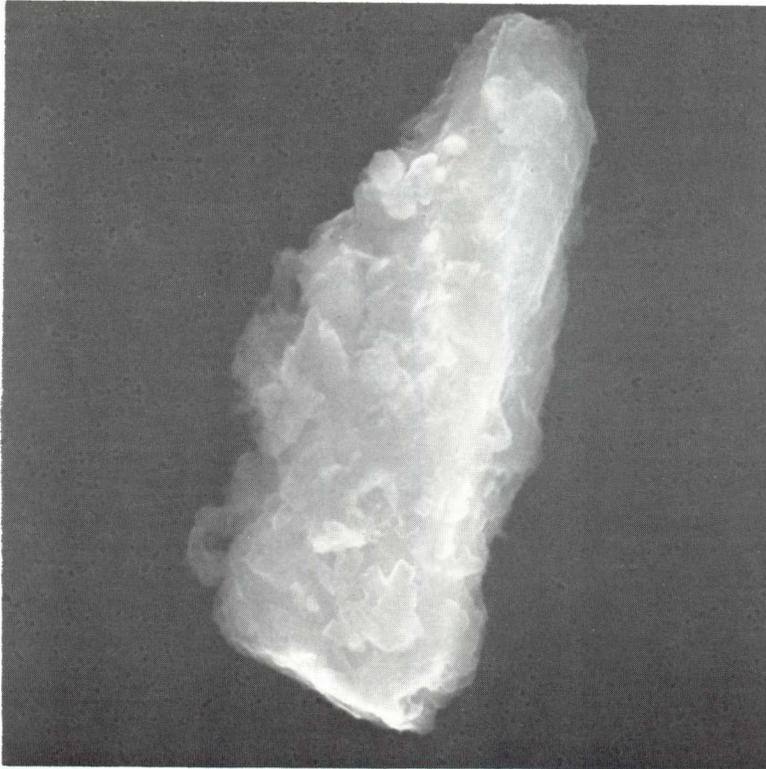
SIZE: 60x38
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D
TYPE: TCN
COMMENTS:

UA1

S-87-45924



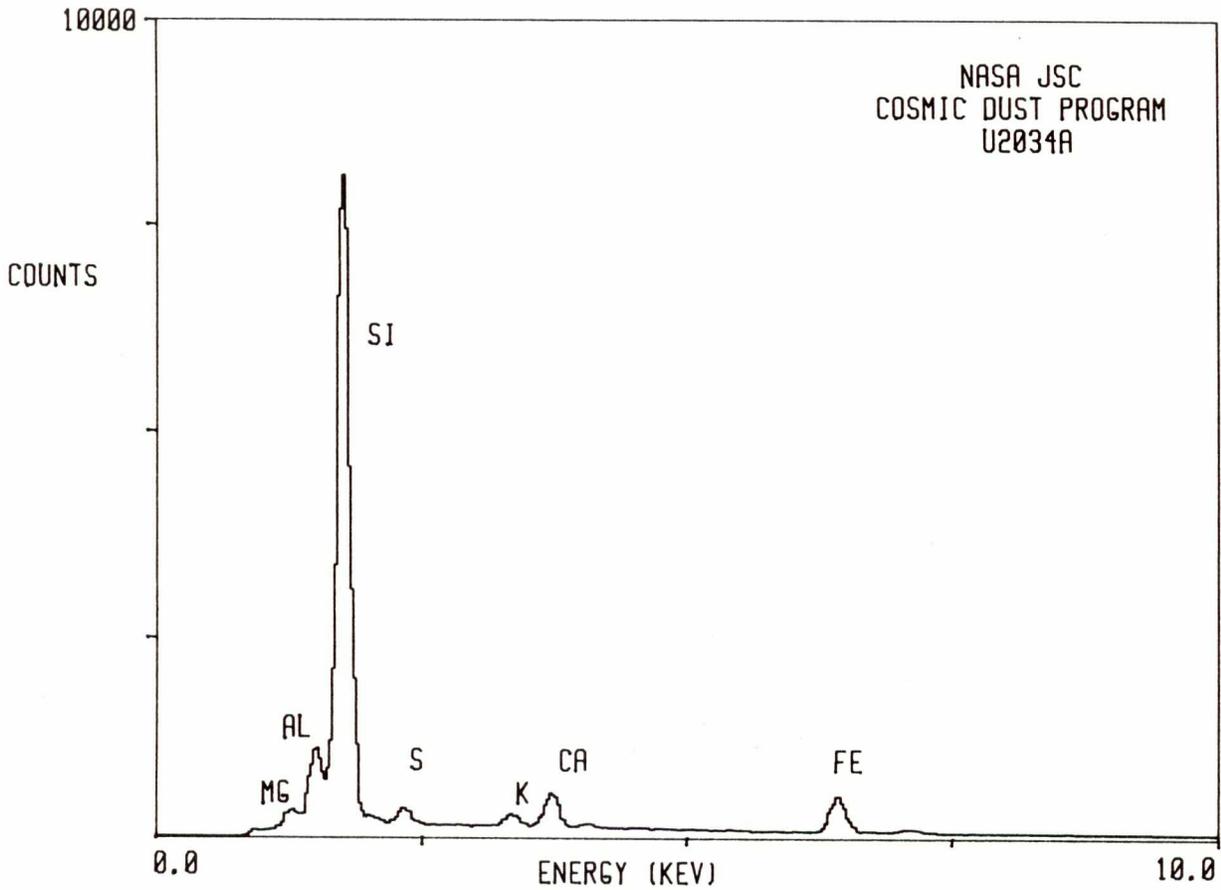
U2034 A 5



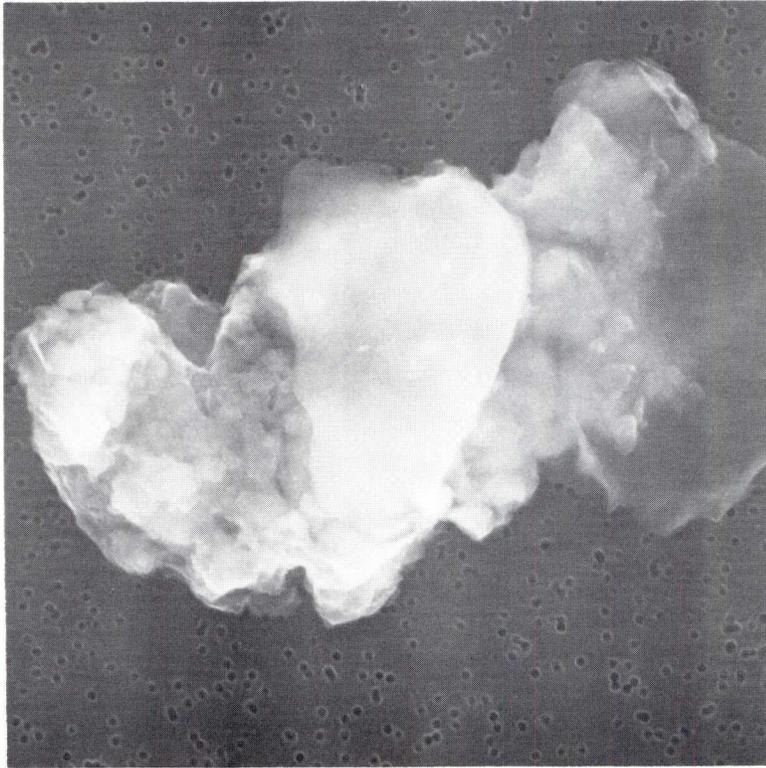
SIZE: 40x12
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCN
COMMENTS:

UA5

S-87-45926



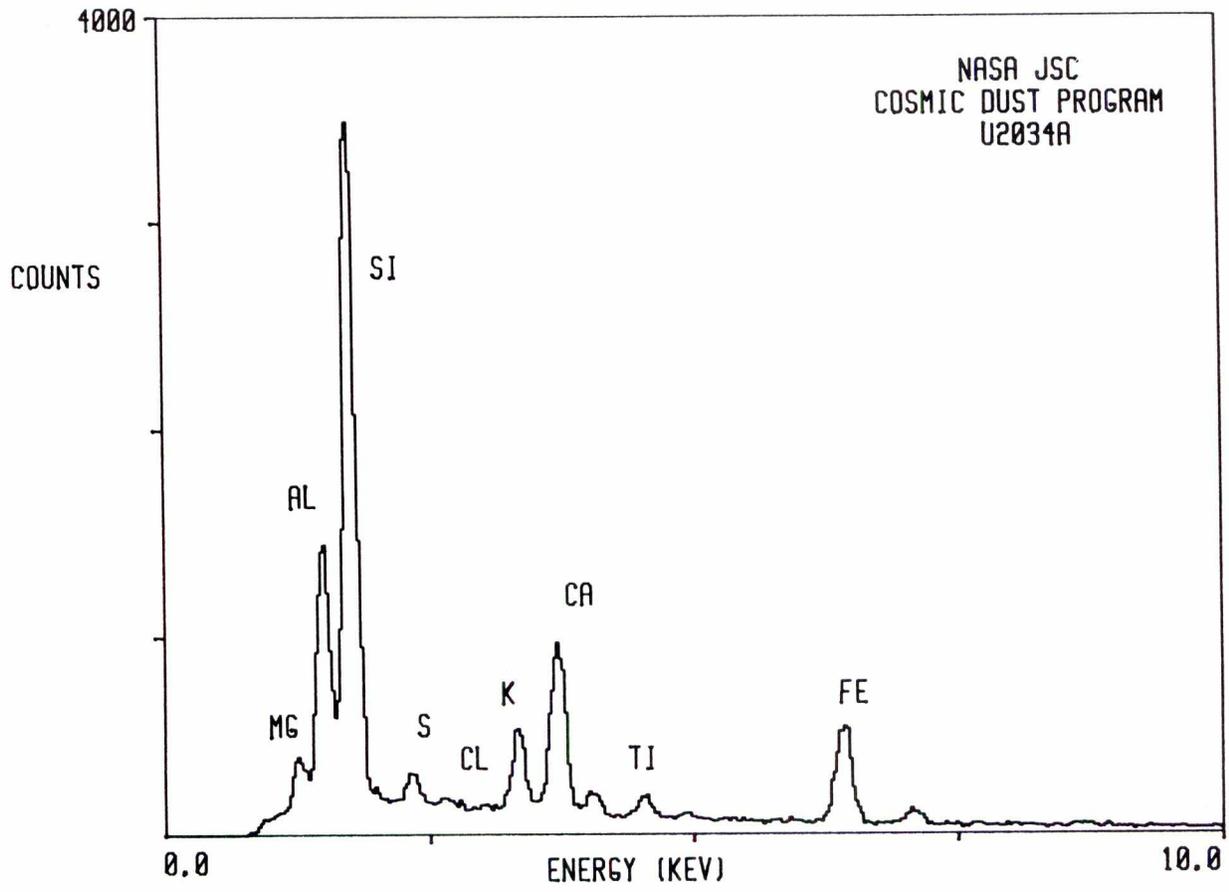
U2034 A 7



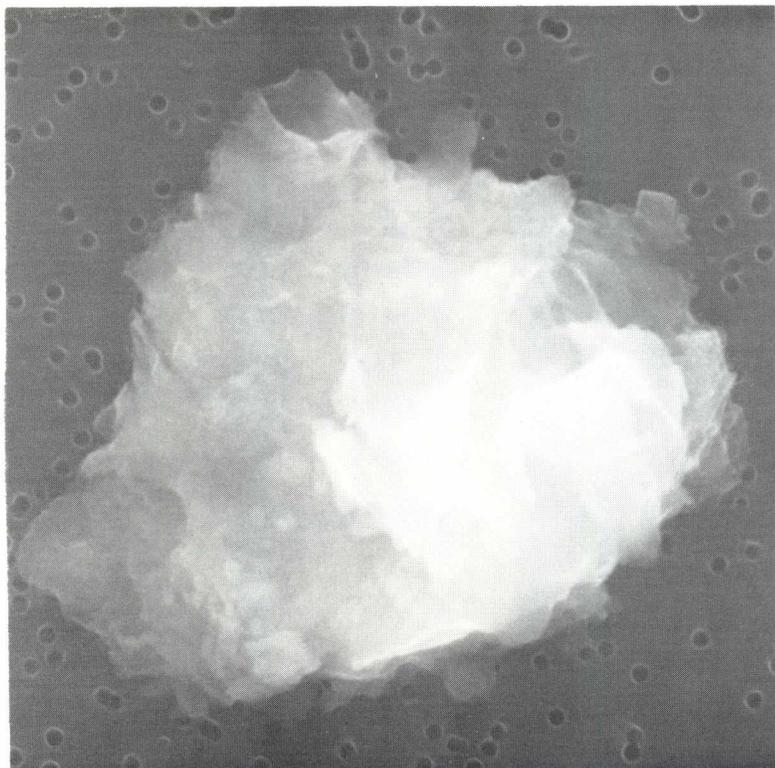
SIZE: 25x15
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D
TYPE: TCN
COMMENTS:

UA7

S-87-45928



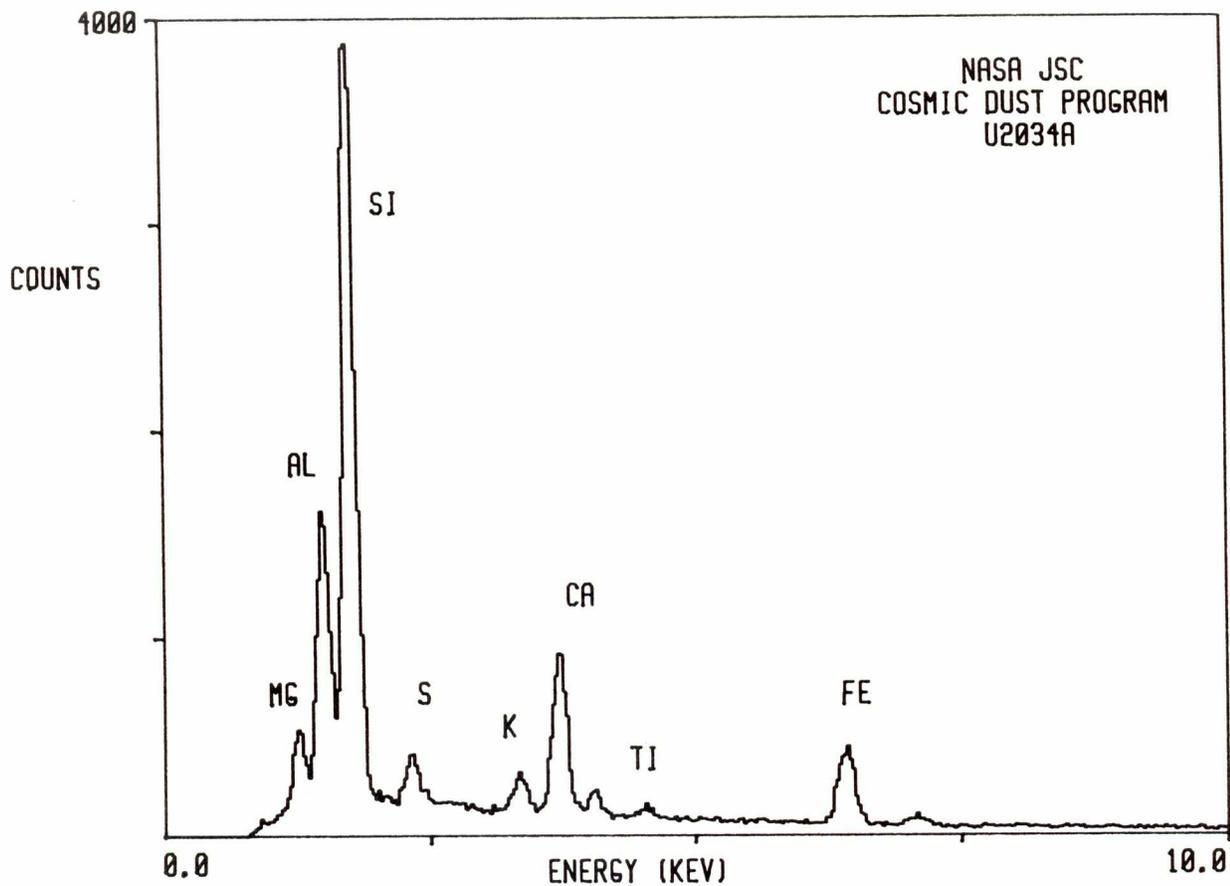
U2034 A 10



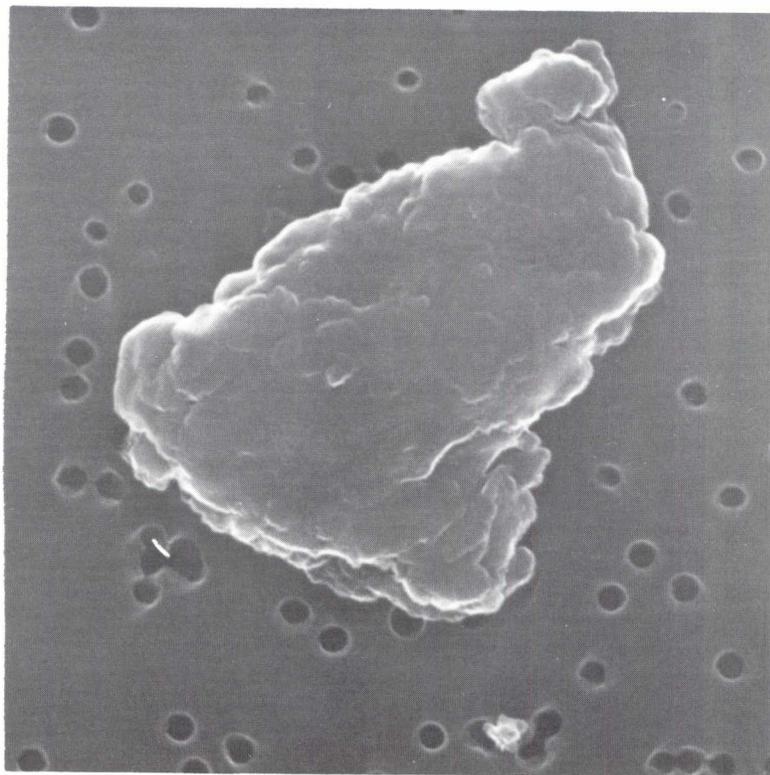
SIZE: 15x12
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCN
COMMENTS:

UR10

S-87-45931



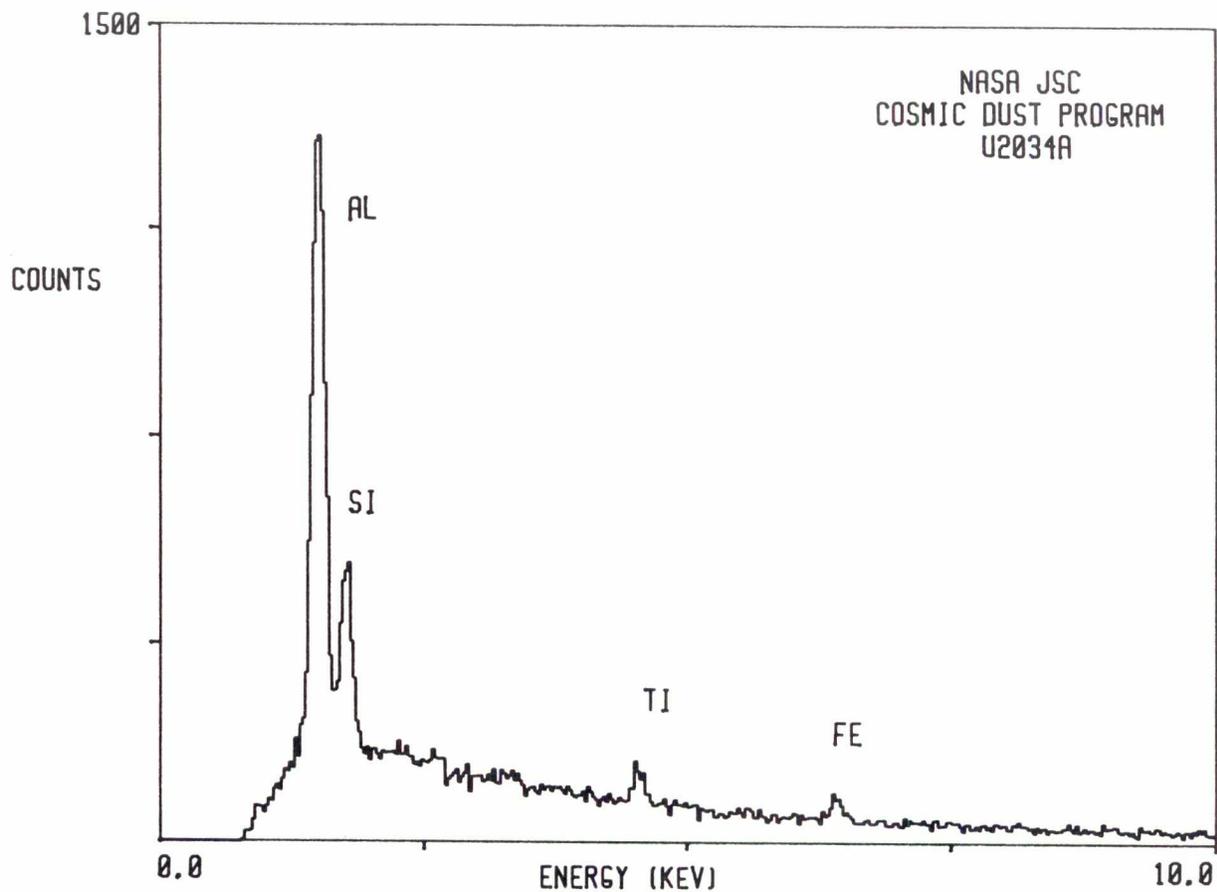
U2034 A 11



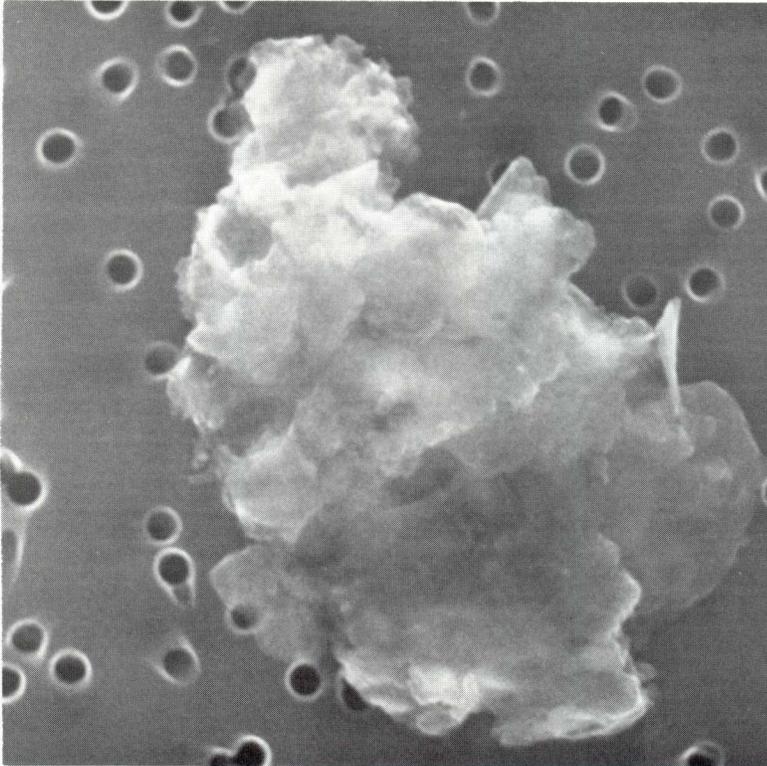
SIZE: 11
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCN
COMMENTS:

UA11

S-87-45932



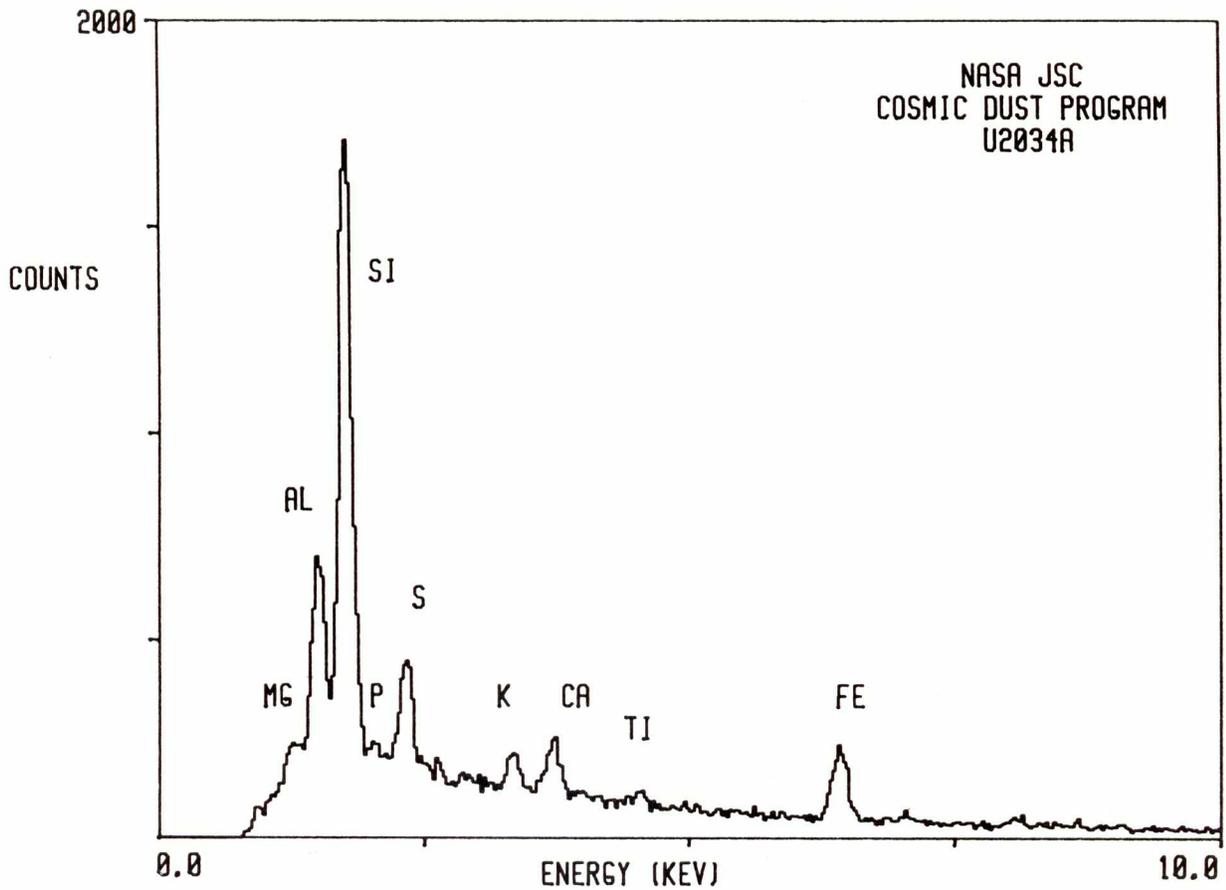
U2034 A 13



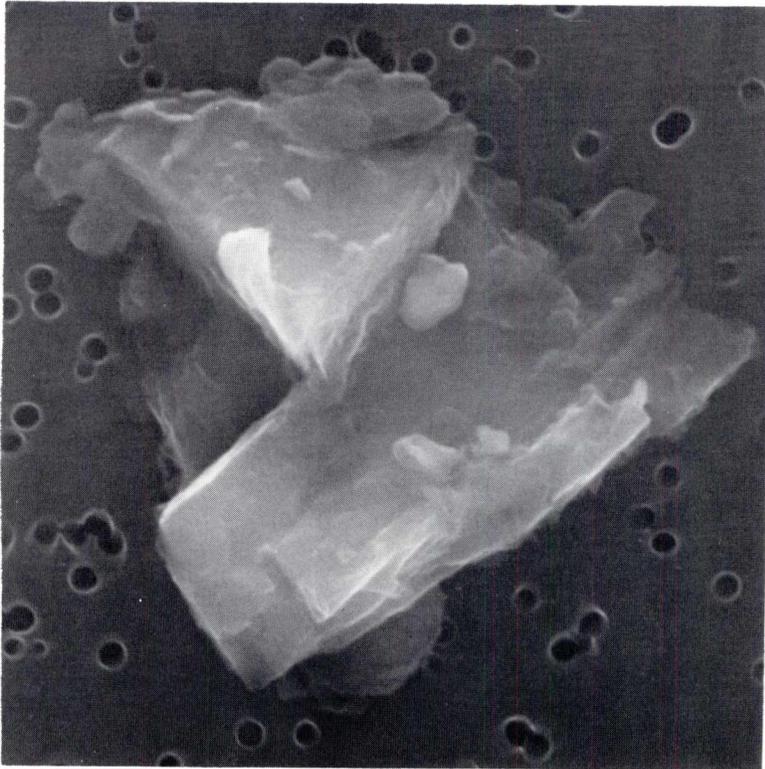
SIZE: 8x4
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D/SM
TYPE: TCN
COMMENTS:

UA13

S-87-45934



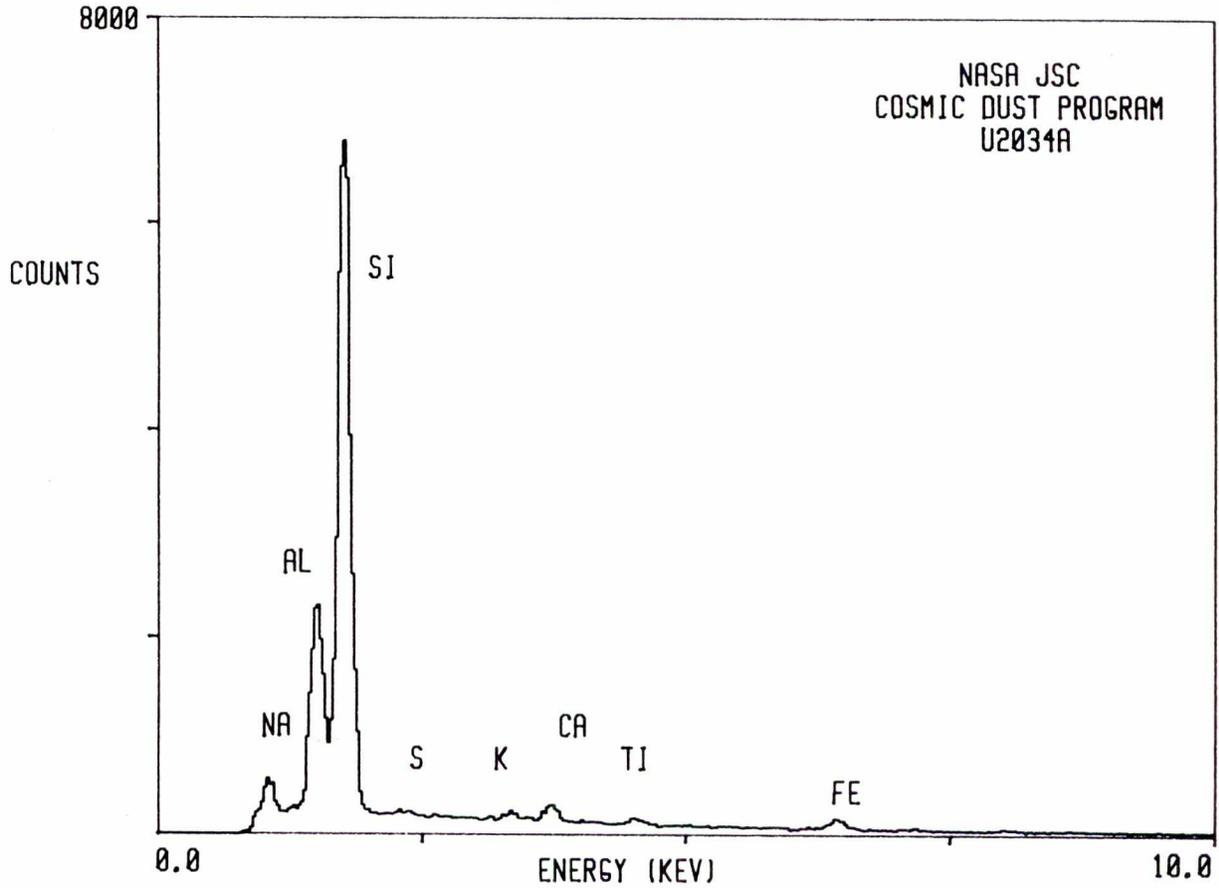
U2034 A 15



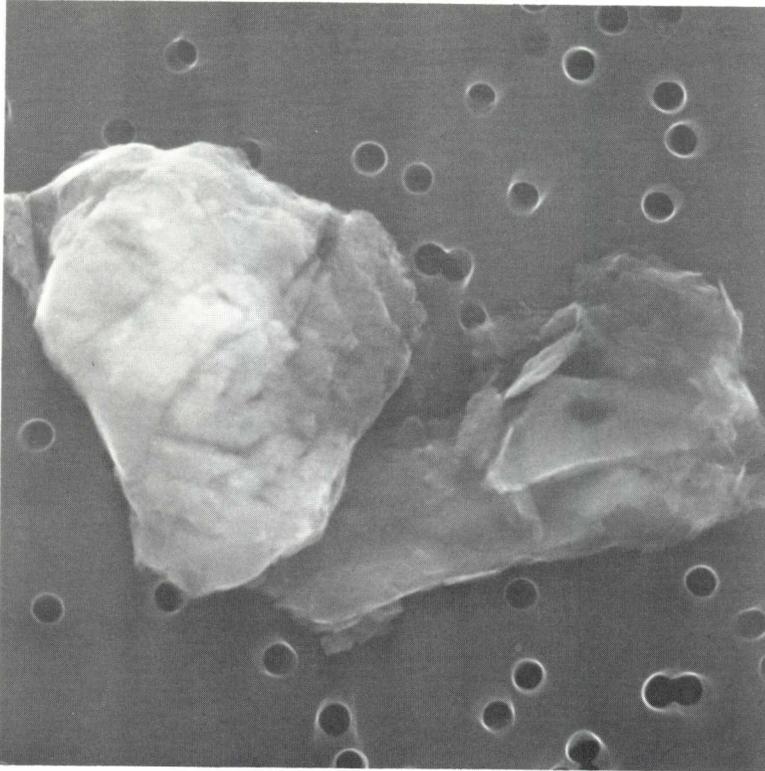
SIZE: 35
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCN
COMMENTS:

UA15

S-87-45936



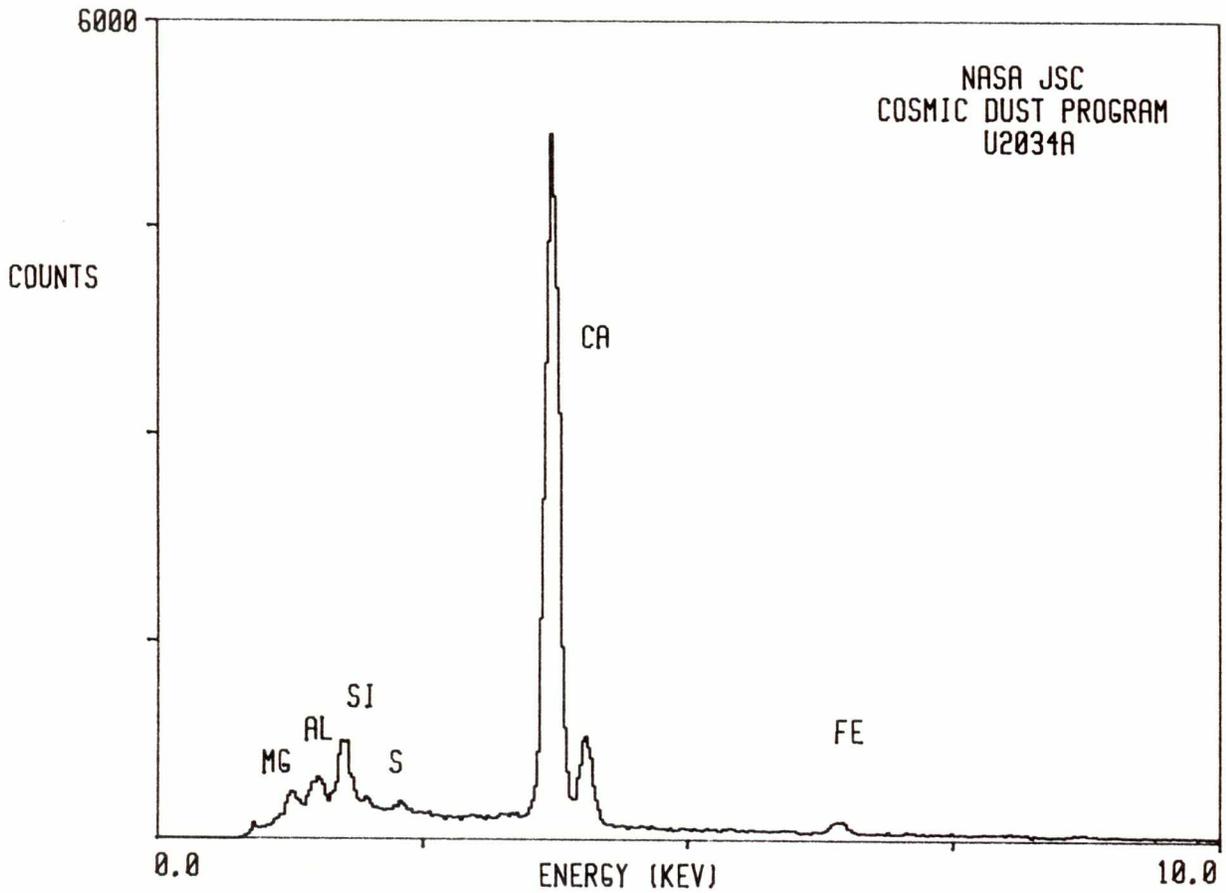
U2034 A 16



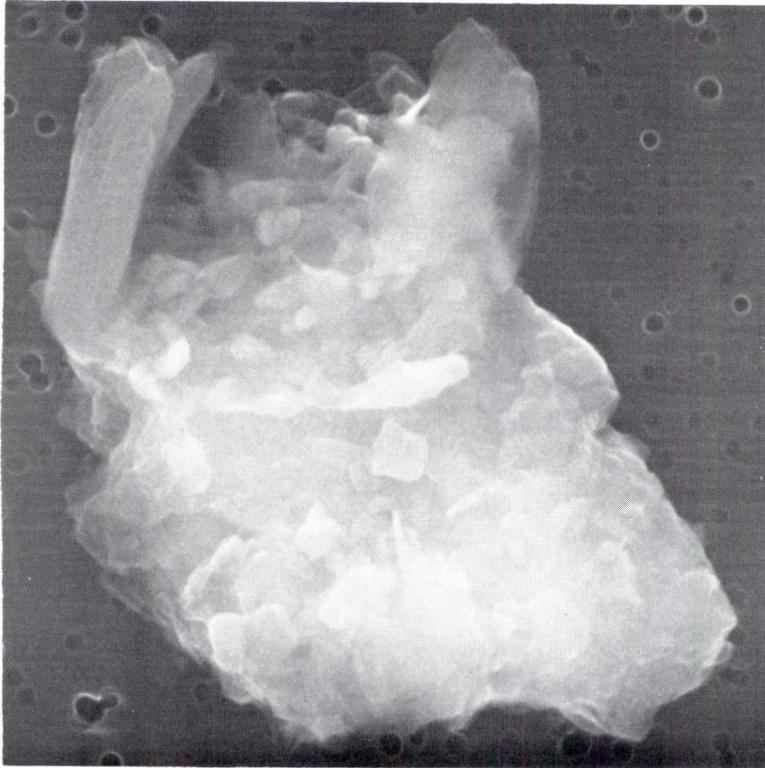
SIZE: 30x25
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCN
COMMENTS:

UA16

S-87-45937



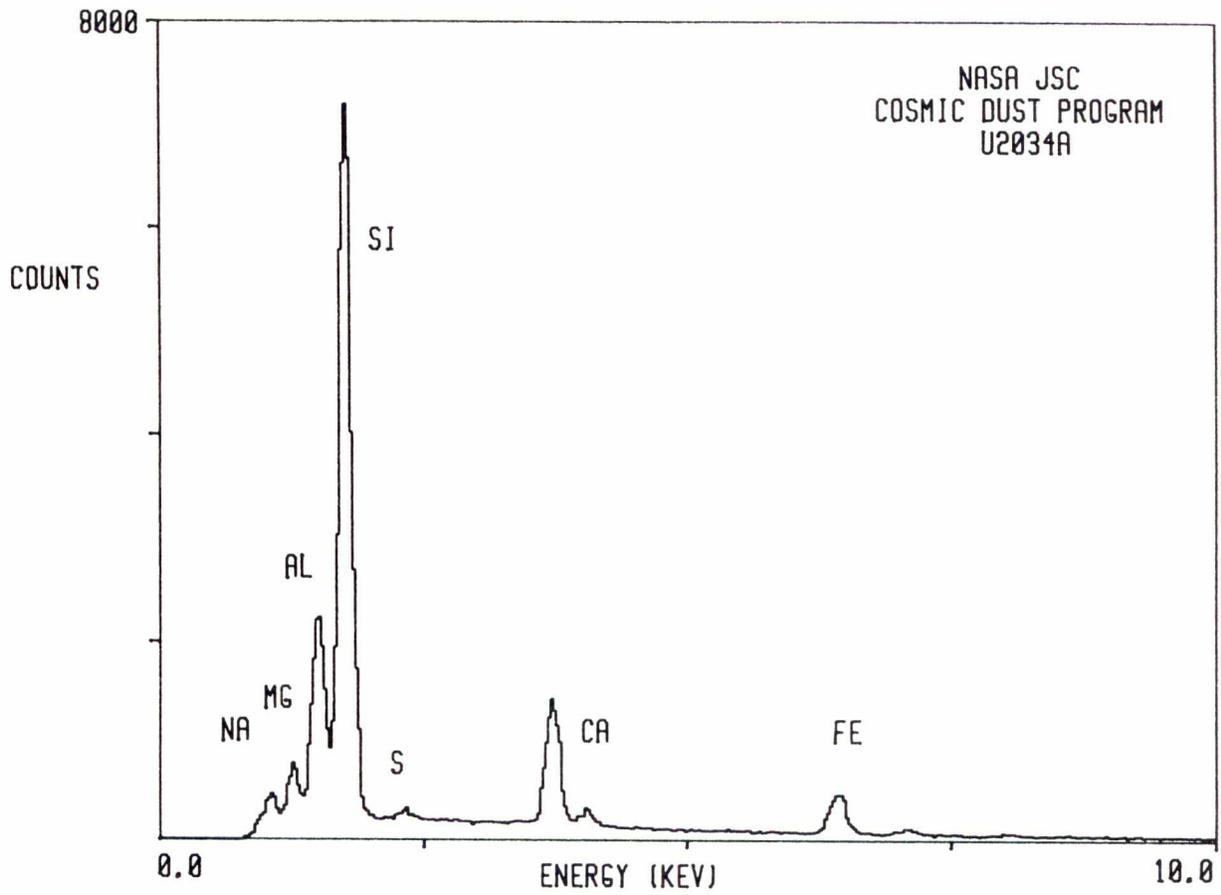
U2034 A 18



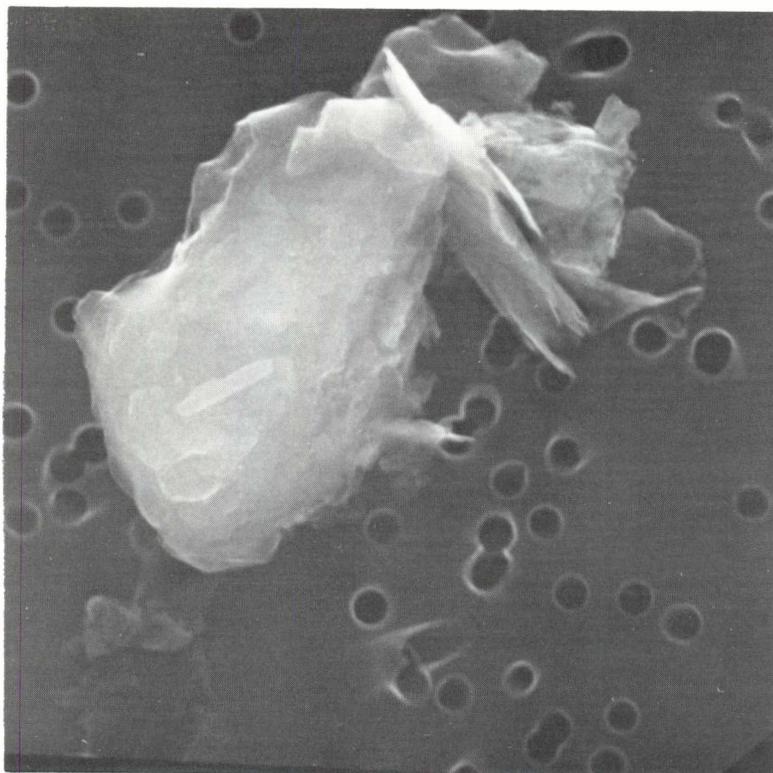
SIZE: 12
SHAPE: I
TRANS.: TL
COLOR: Yellow
LUSTER: SV
TYPE: TCN
COMMENTS:

UR18

S-87-45939



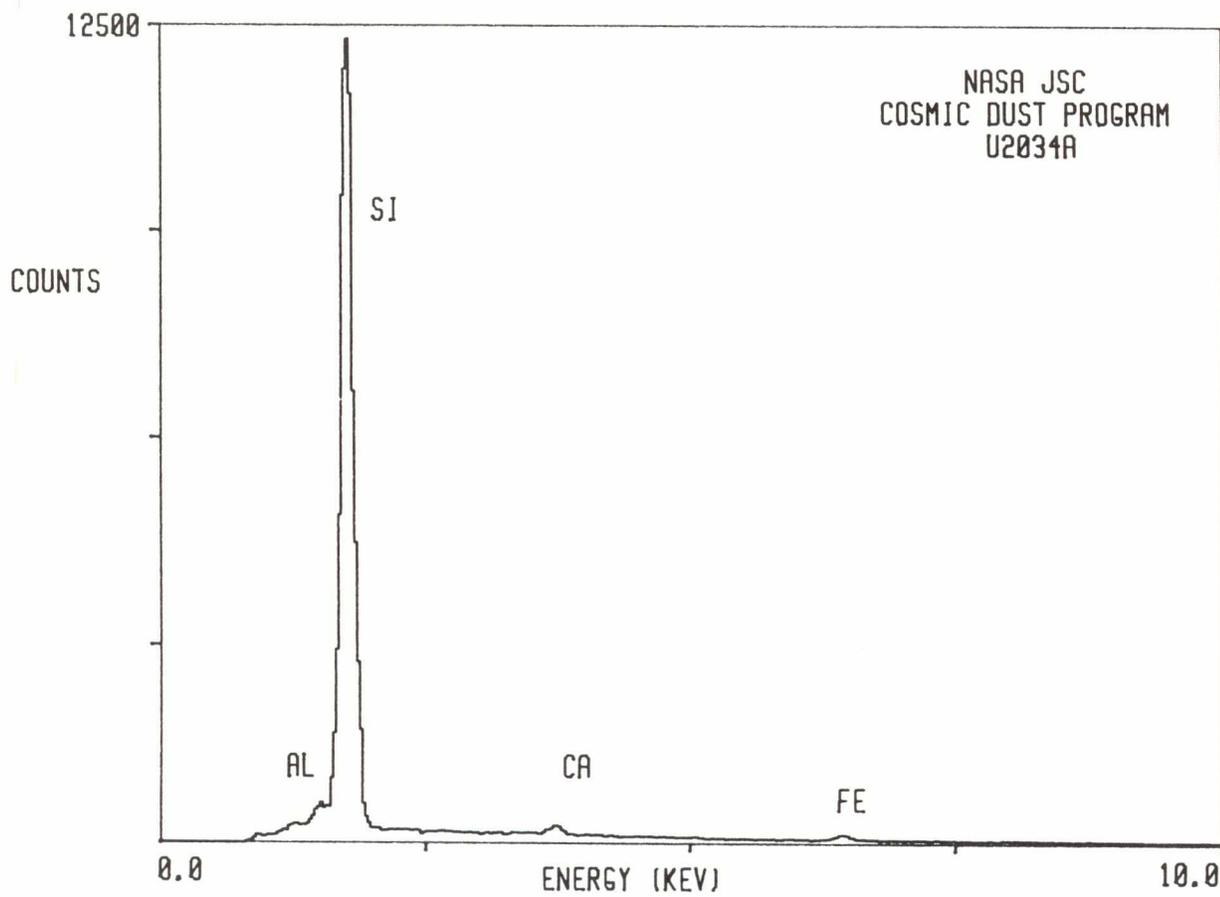
U2034 A 19



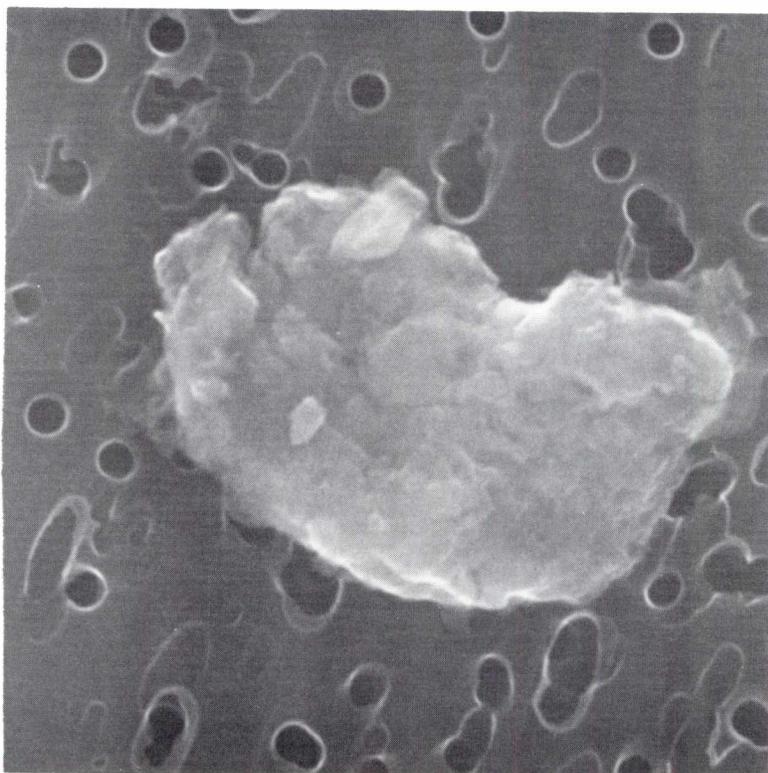
SIZE: 5
SHAPE: I
TRANS.: TL
COLOR: Yellow
LUSTER: SV
TYPE: TCN
COMMENTS:

UA19

S-87-45940



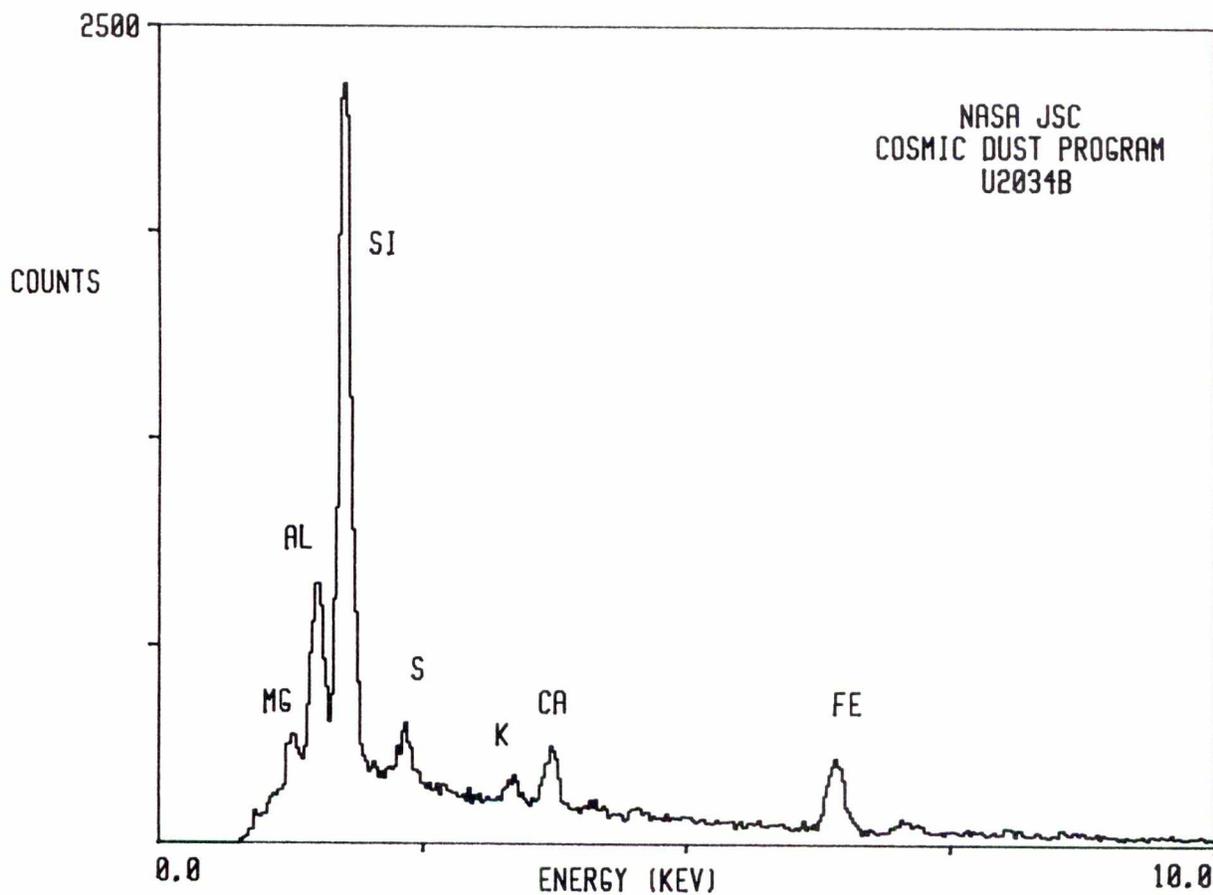
U2034 B 9



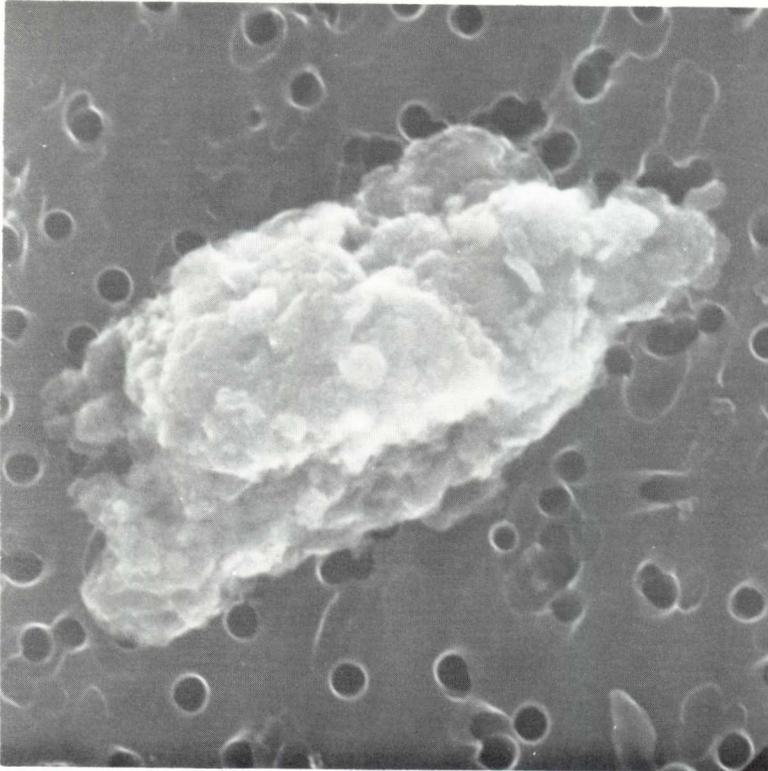
SIZE: 7x5
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: TCN
COMMENTS:

UB9

S-87-45952



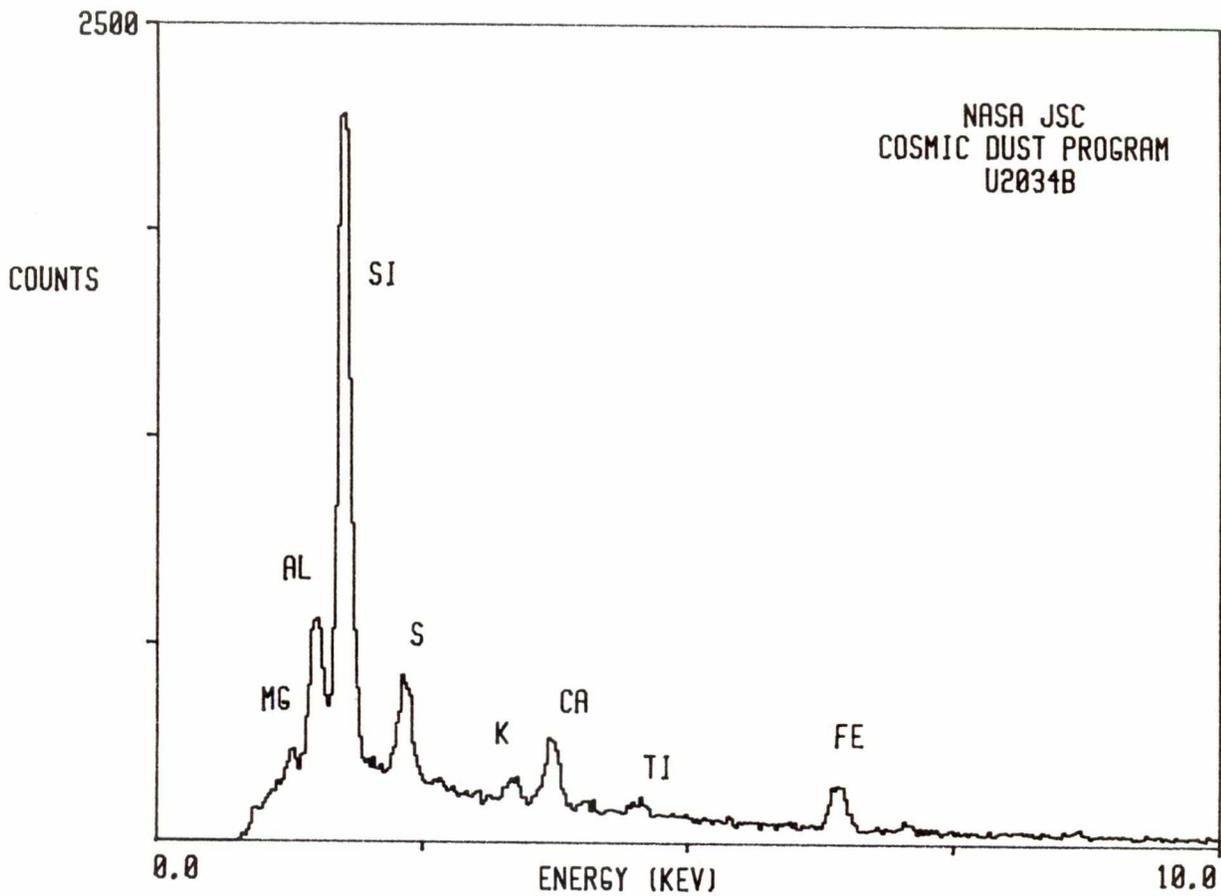
U2034 B 10



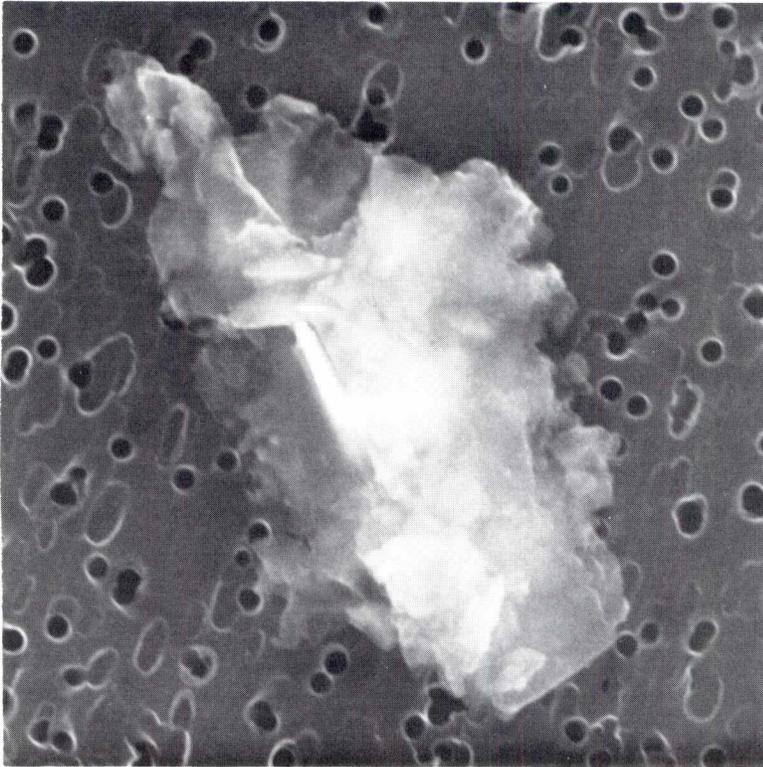
SIZE: 8x4
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: TCN
COMMENTS:

UB10

S-87-45953



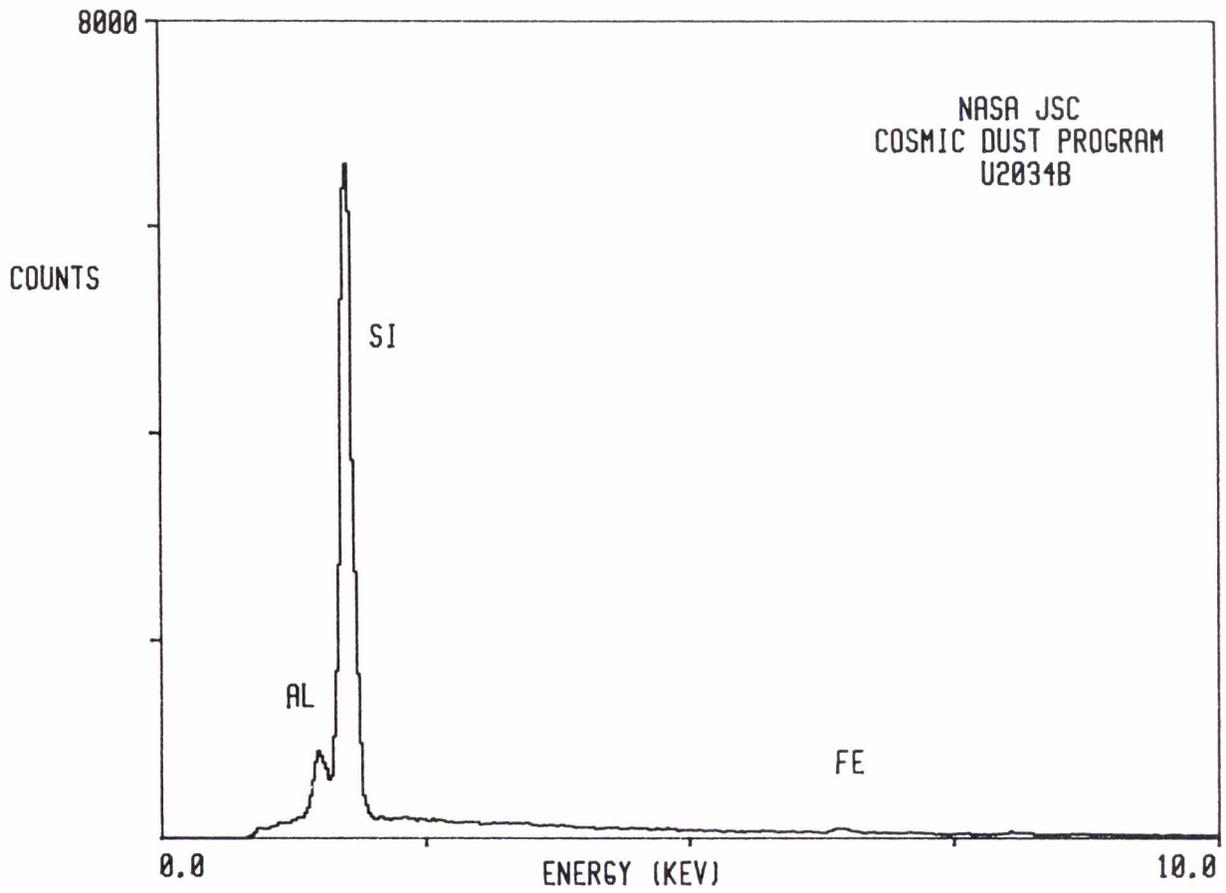
U2034 B 14



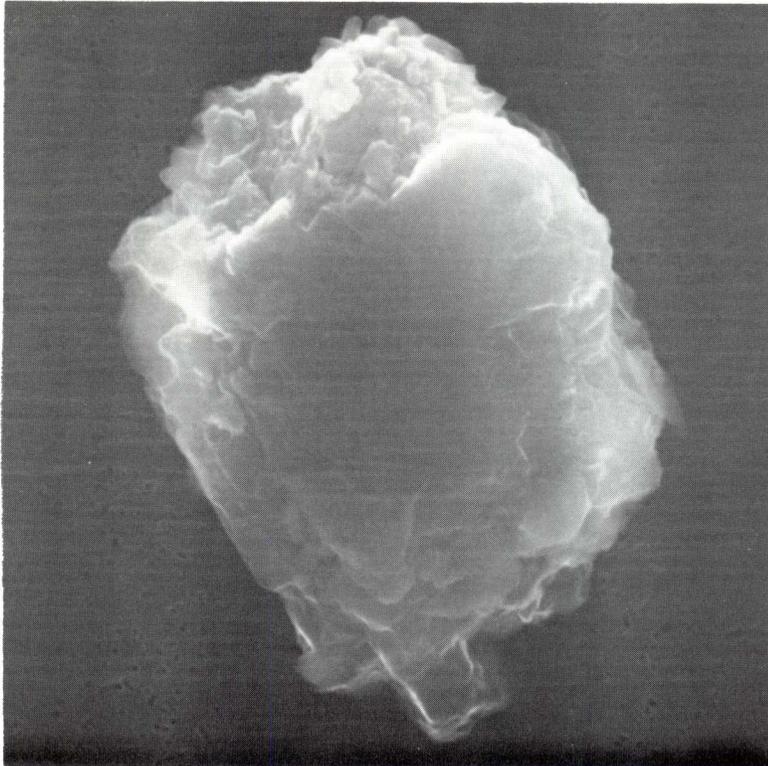
SIZE: 10x5
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: TCN
COMMENTS:

UB14

S-87-45957



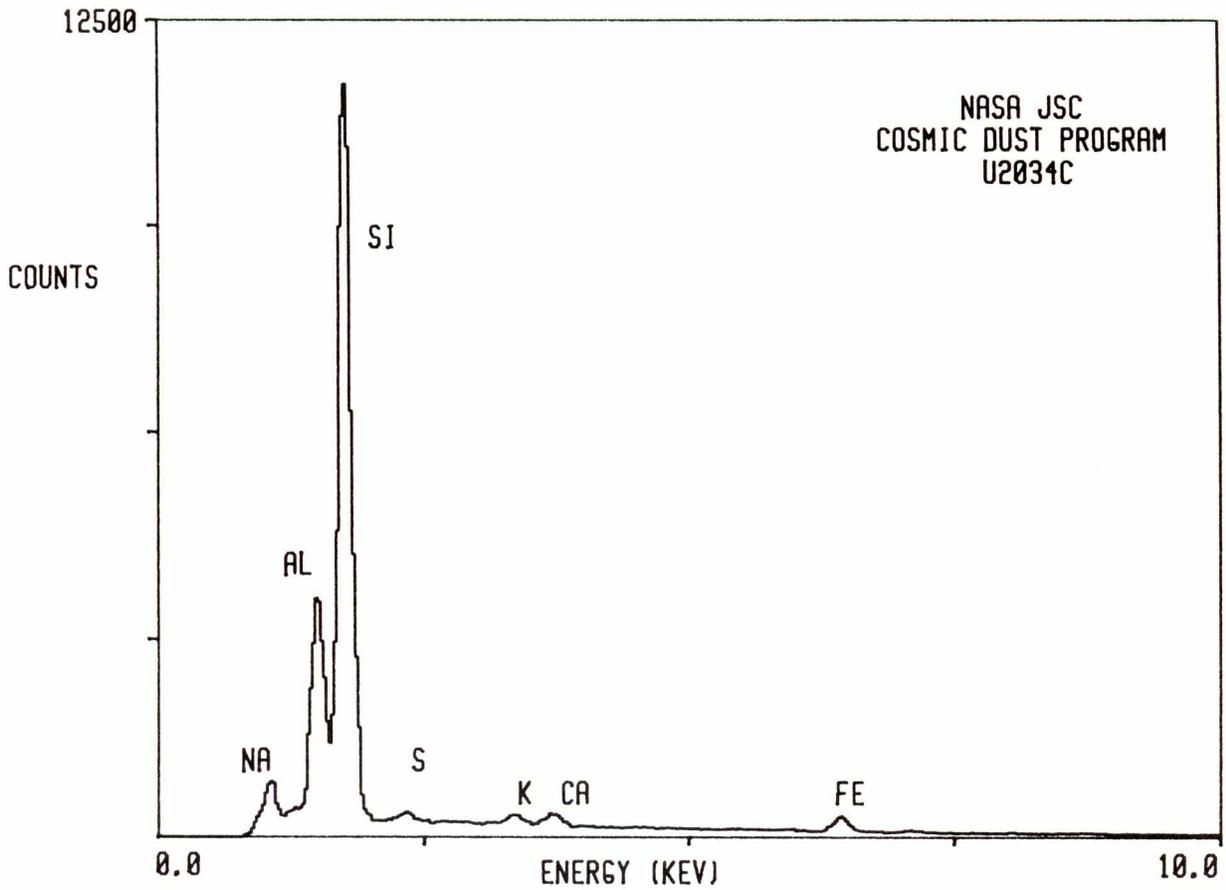
U2034 C 3



SIZE: 25
SHAPE: I
TRANS.: TL
COLOR: Yellow
LUSTER: SV
TYPE: TCN
COMMENTS:

UC3

S-87-45963



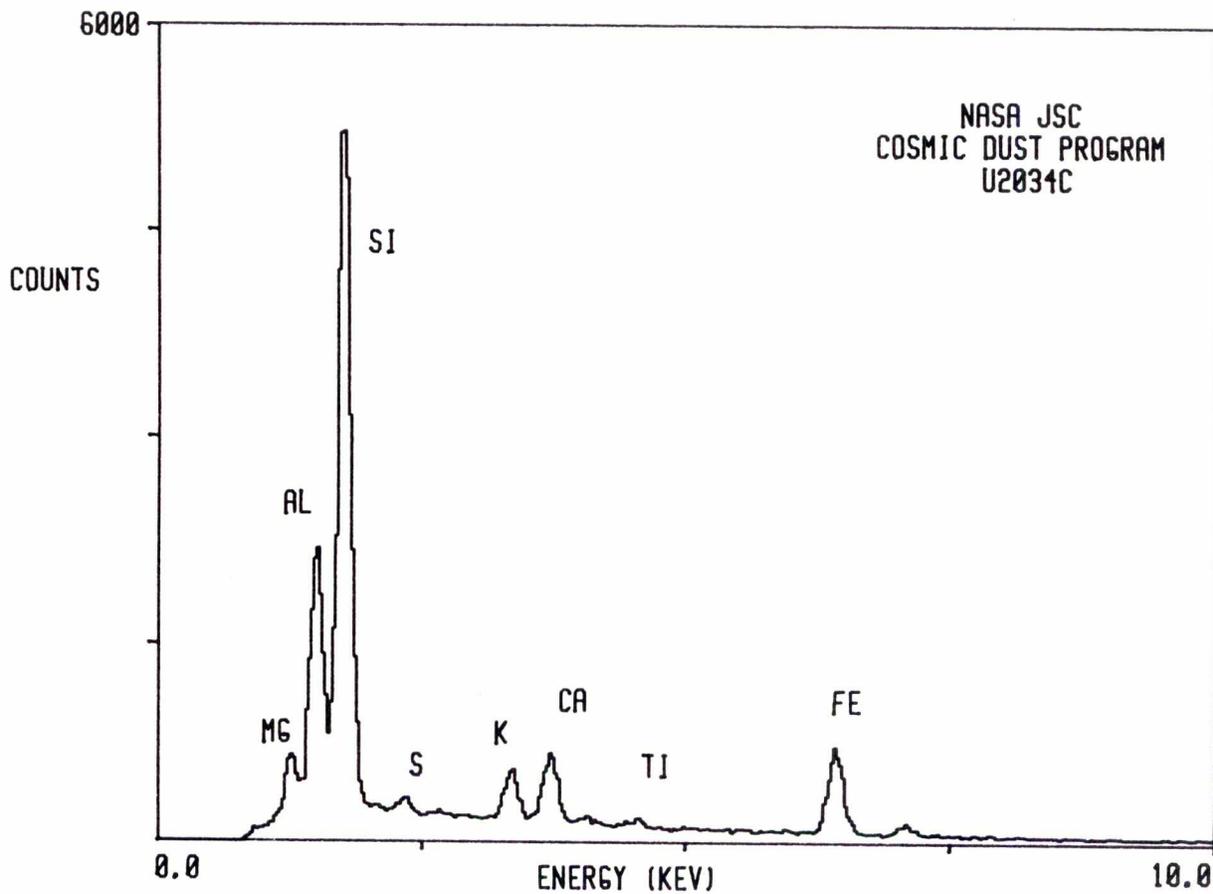
U2034 C 8



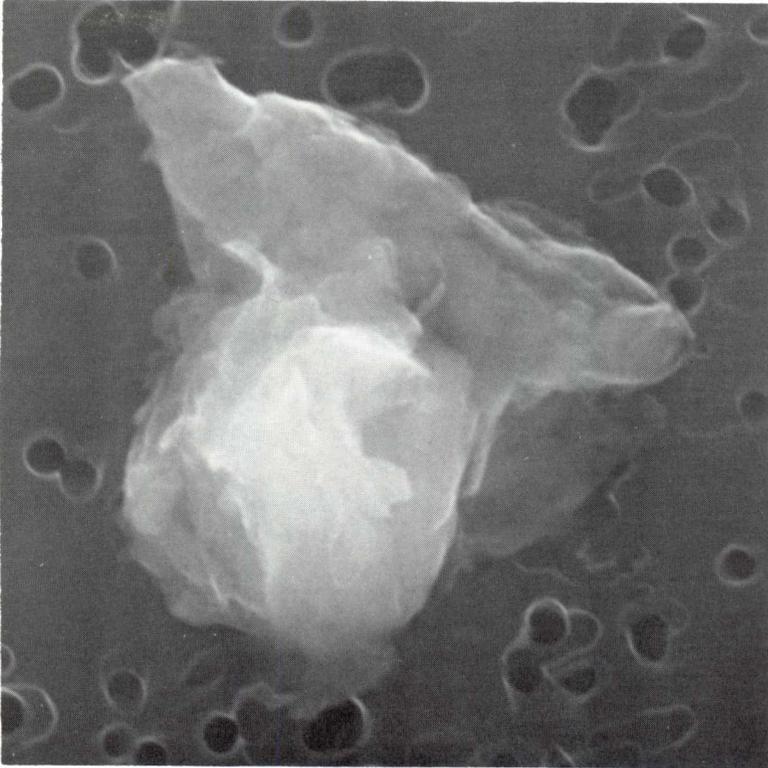
SIZE: 15x11
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCN
COMMENTS:

UC8

S-87-45966



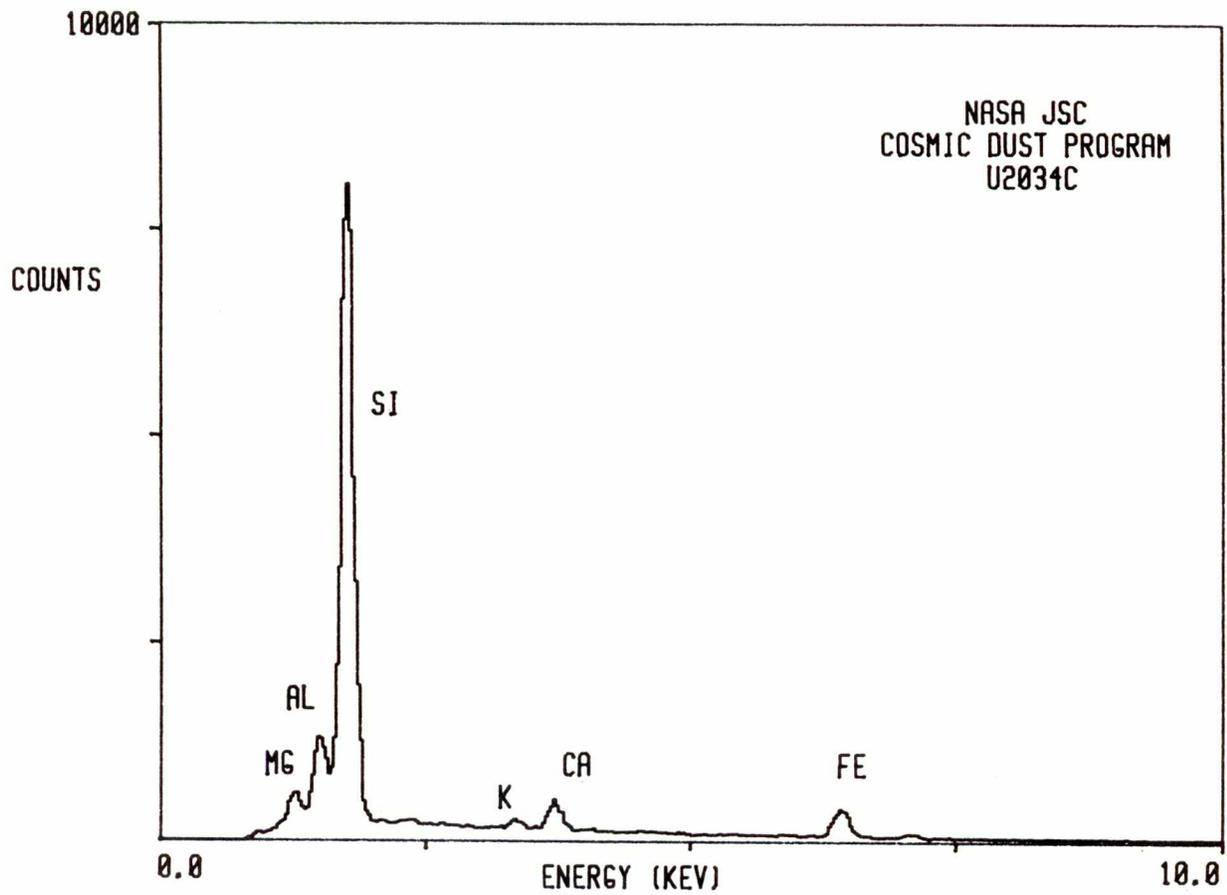
U2034 C 9



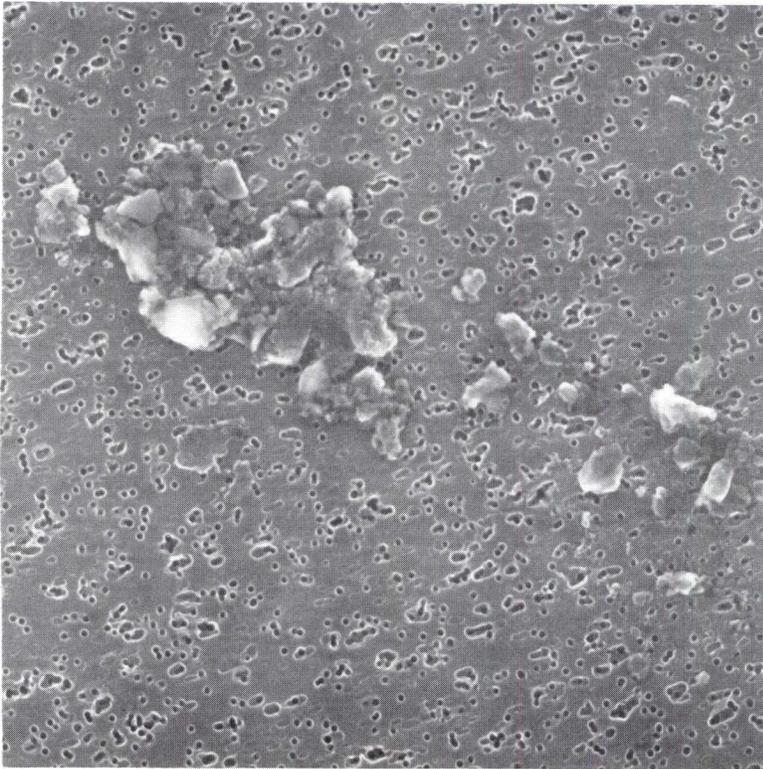
SIZE: 30x22
SHAPE: I
TRANS.: O/T
COLOR: Black to red-brown
LUSTER: D/SV
TYPE: TCN
COMMENTS:

UC9

S-87-45968



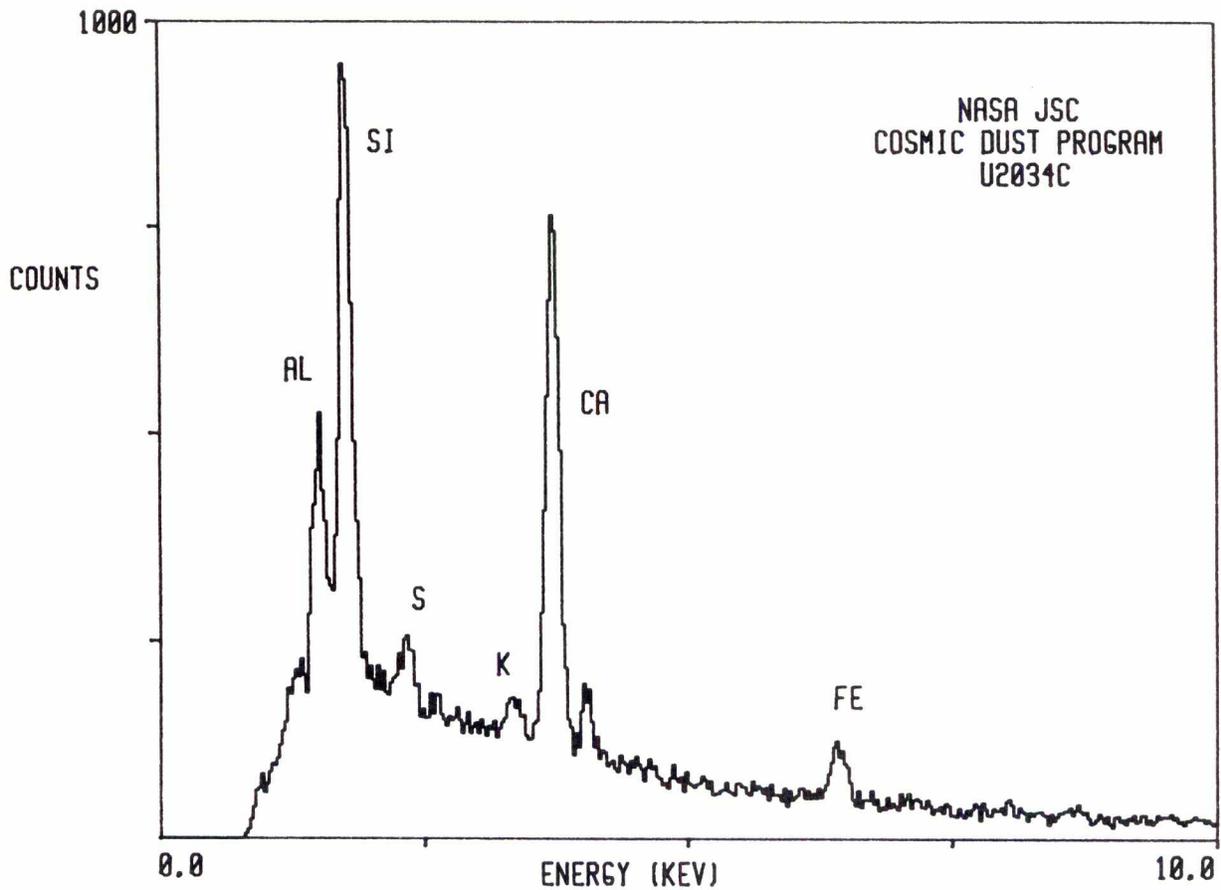
U2034 C 14



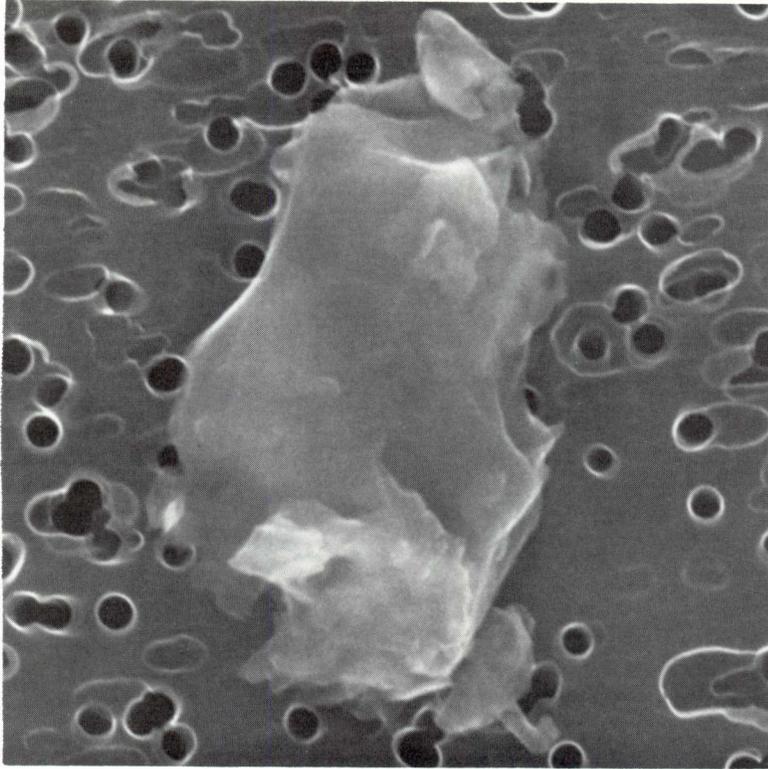
SIZE: 40x10
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCN
COMMENTS:
Field of particles

UC14

S-87-45973

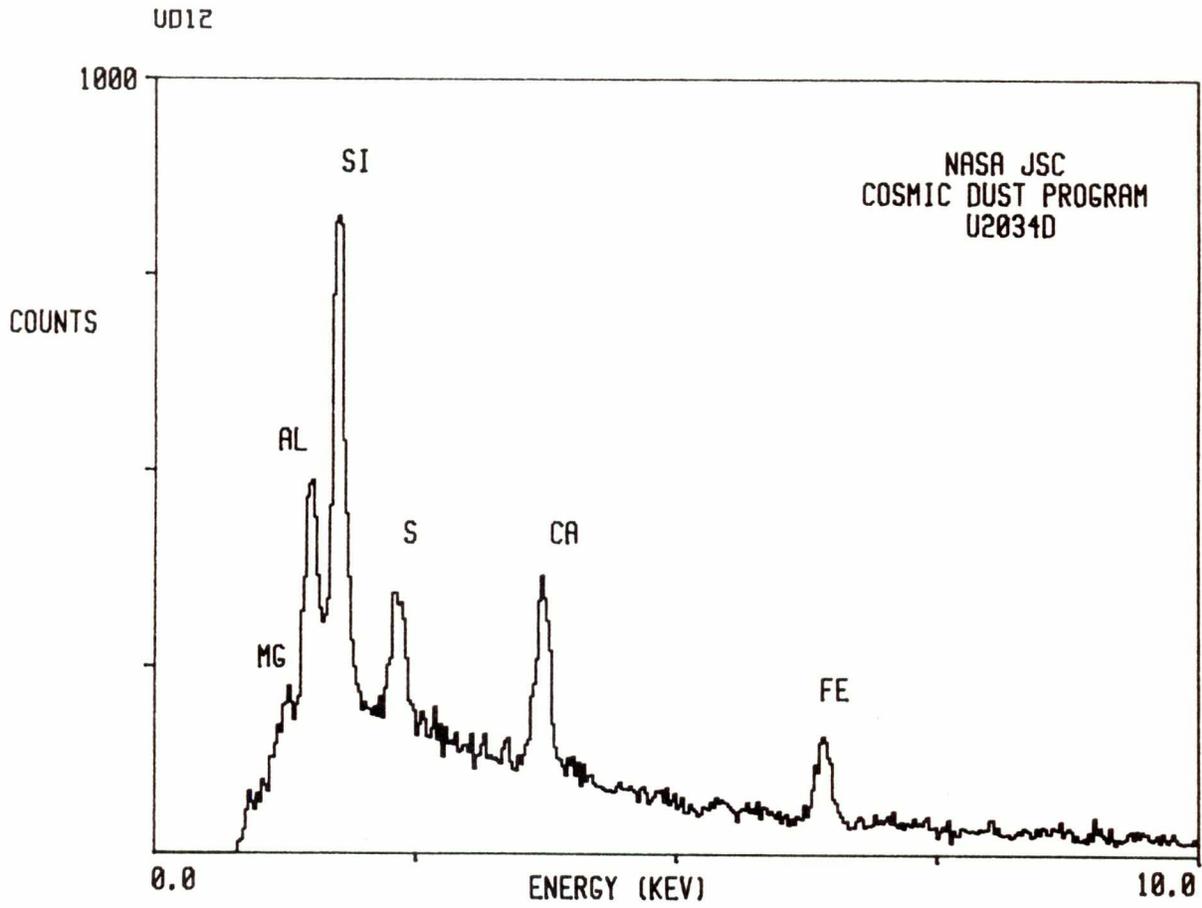


U2034 D 12

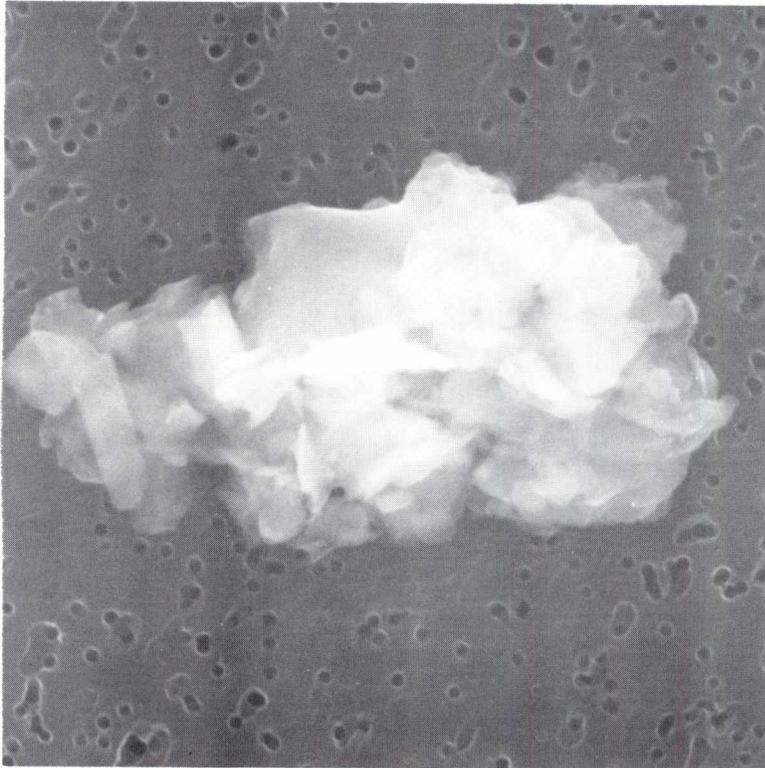


SIZE: 30x20
SHAPE: I
TRANS.: O
COLOR: Reddish-brown
LUSTER: D
TYPE: TCN
COMMENTS:

S-87-45990

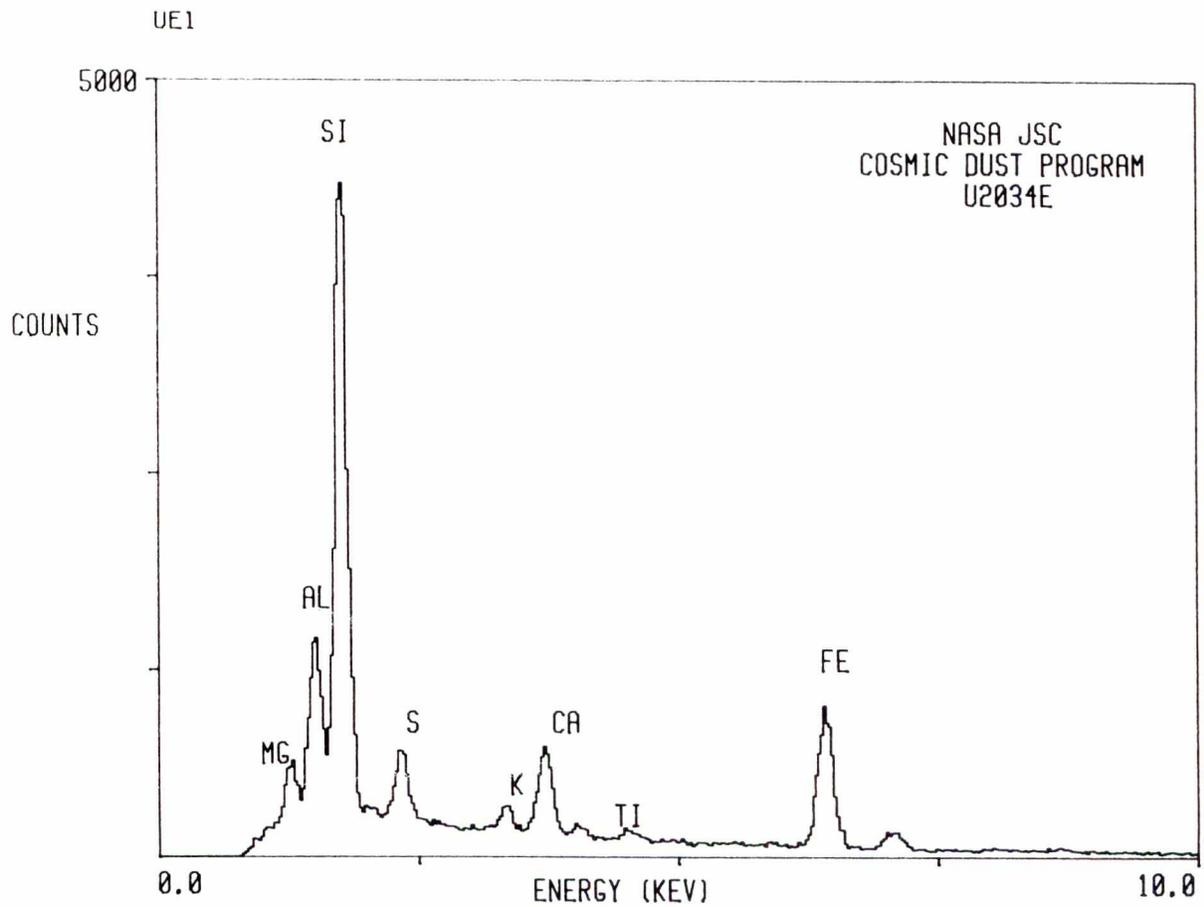


U2034 E 1

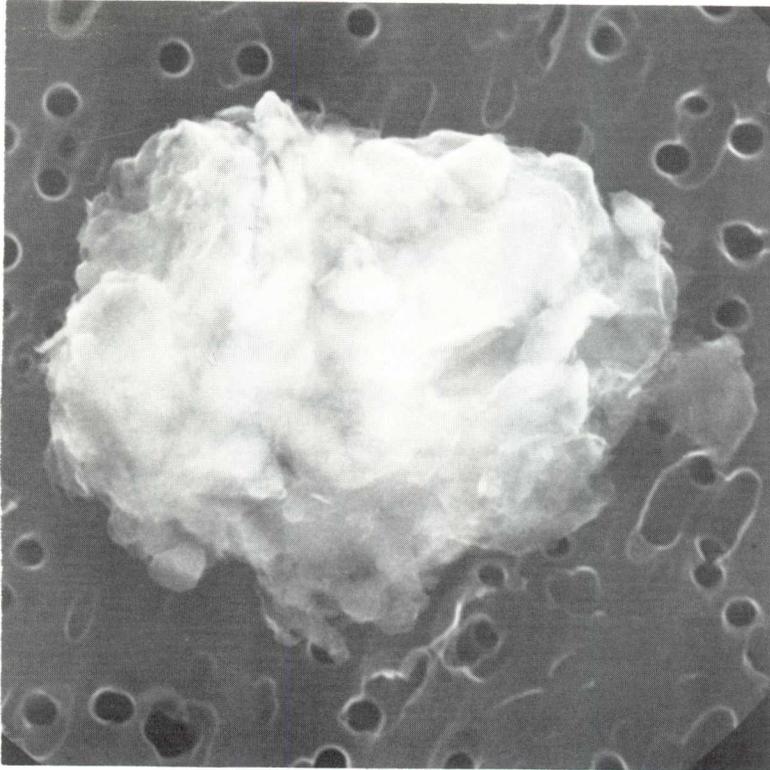


SIZE: 16x10
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCN
COMMENTS:

S-87-45997

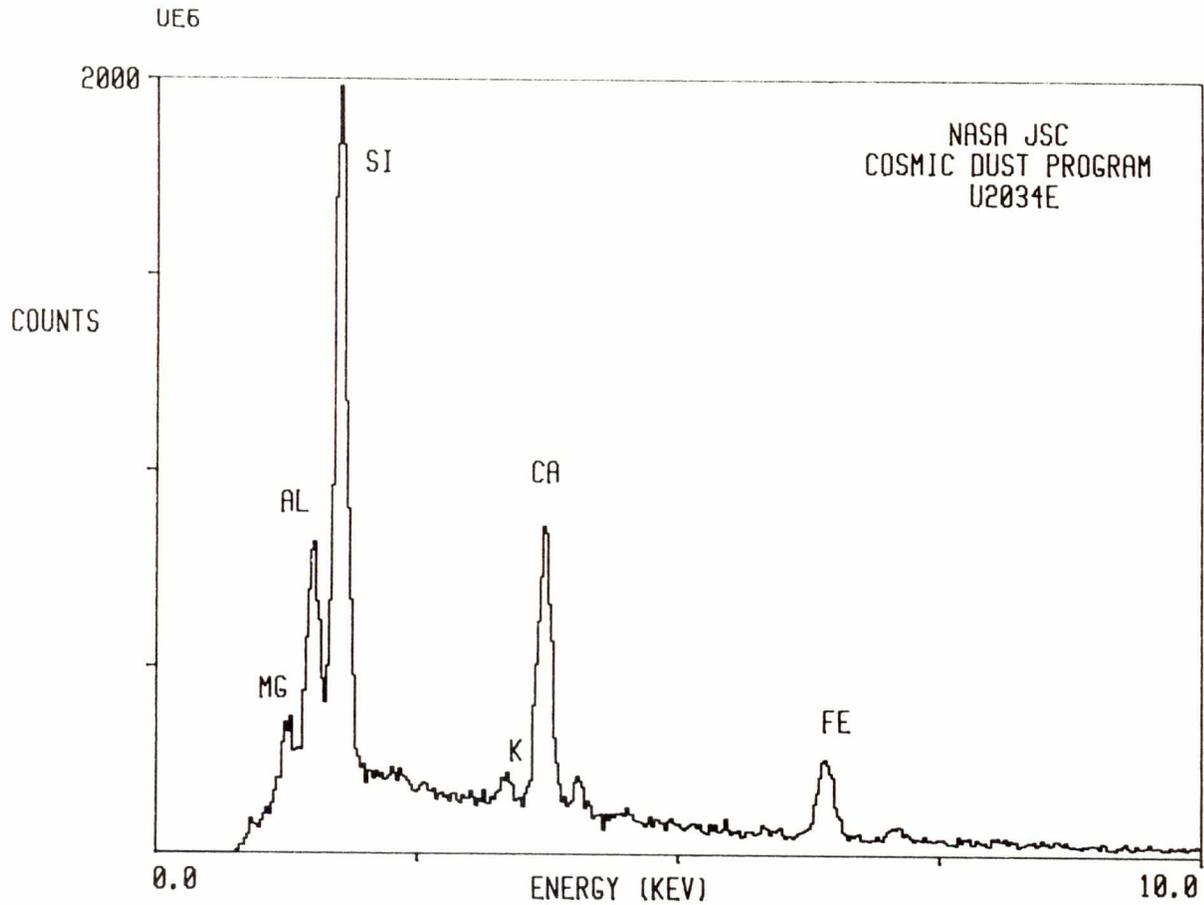


U2034 E 6

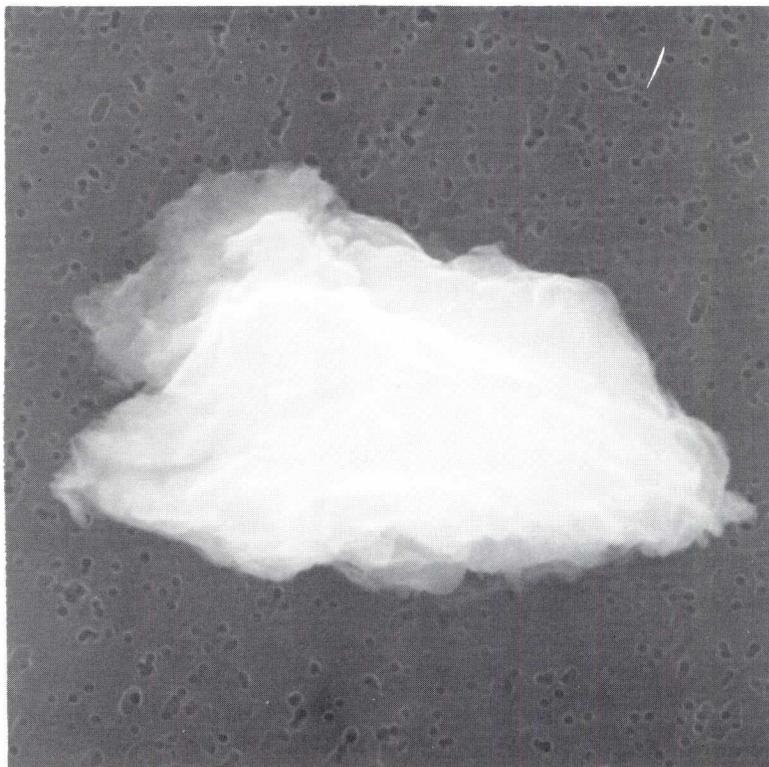


SIZE: 12x10
SHAPE: I
TRANS.: O
COLOR: Black to brown
LUSTER: D/SM
TYPE: TCN
COMMENTS:

S-87-46002

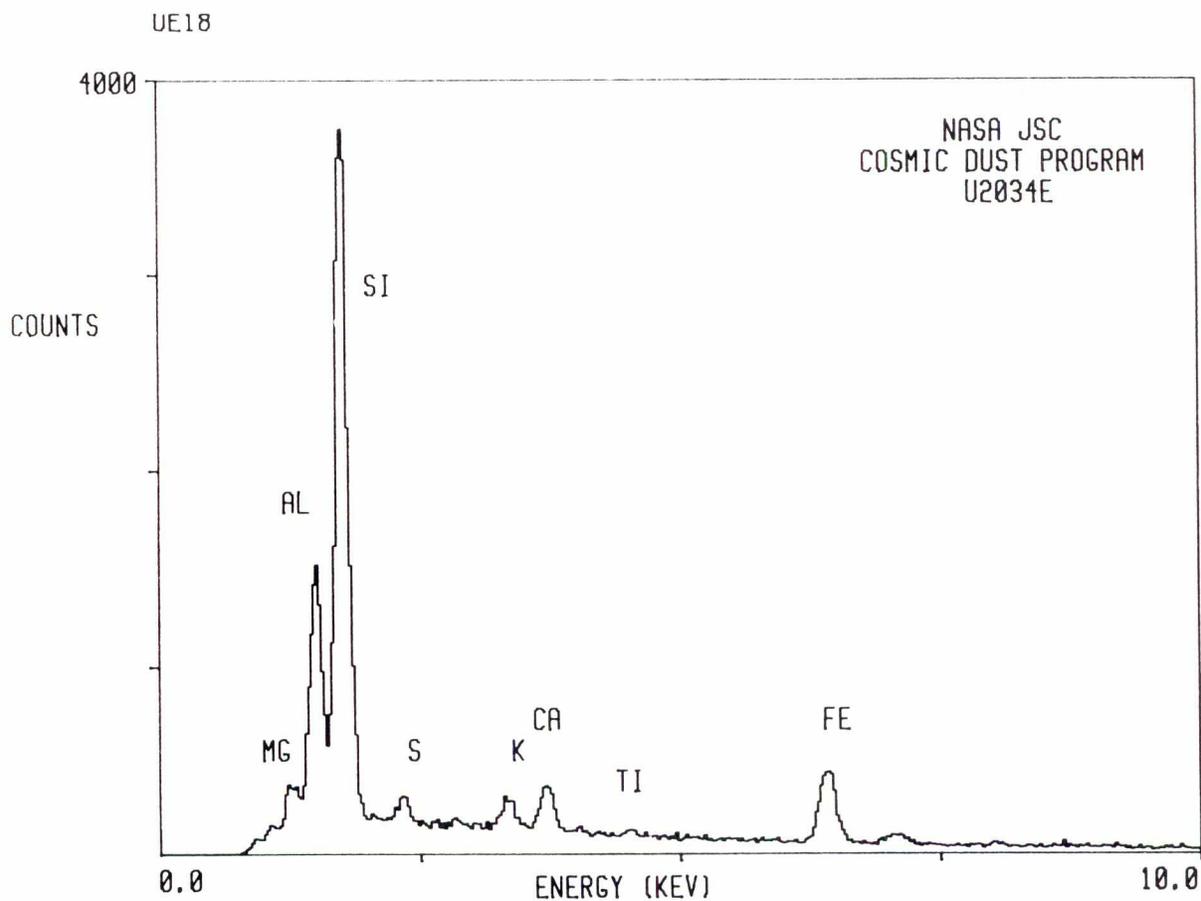


U2034 E 18

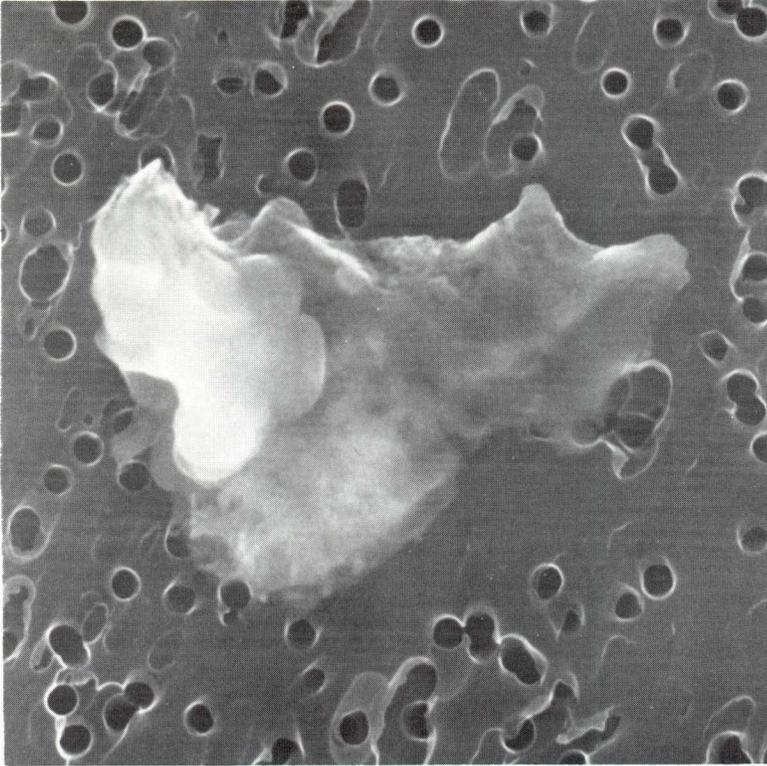


SIZE: 22x10
SHAPE: I
TRANS.: O/TL
COLOR: Brown to white
LUSTER: D/SV
TYPE: TCN
COMMENTS:

S-87-46012

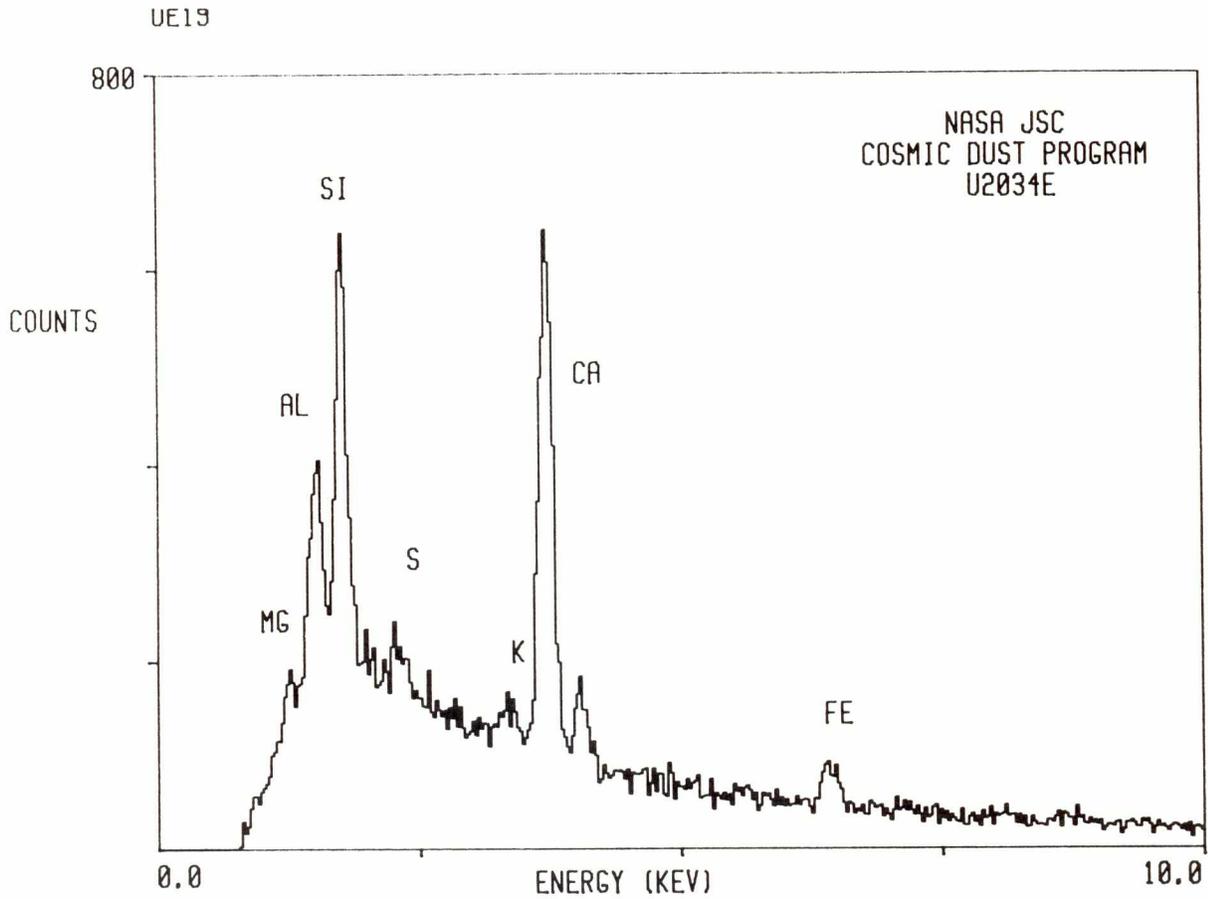


U2034 E 19

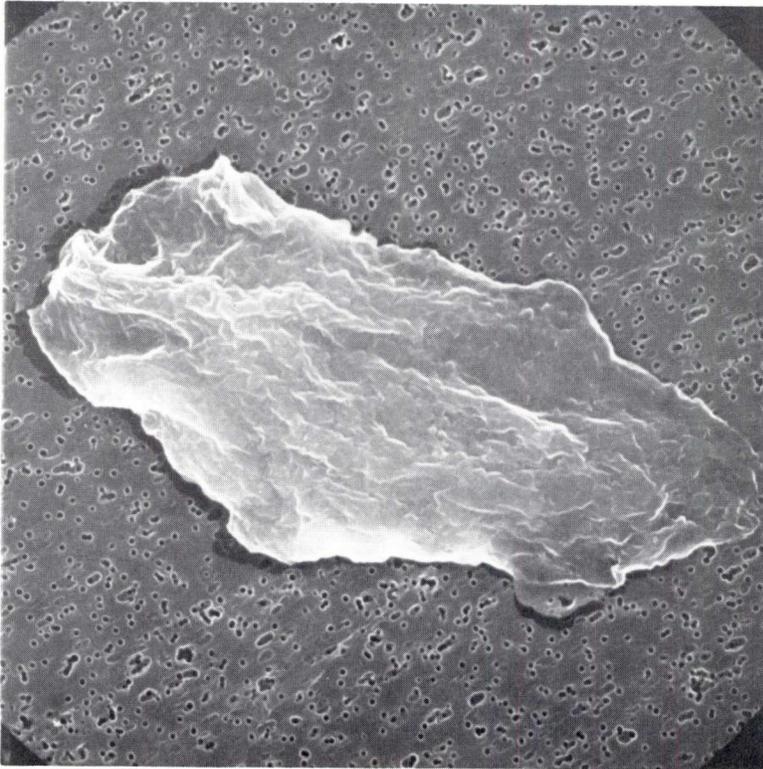


SIZE: 7x4
SHAPE: I
TRANS.: O
COLOR: Brown
LUSTER: D
TYPE: TCN
COMMENTS:

S-87-46013

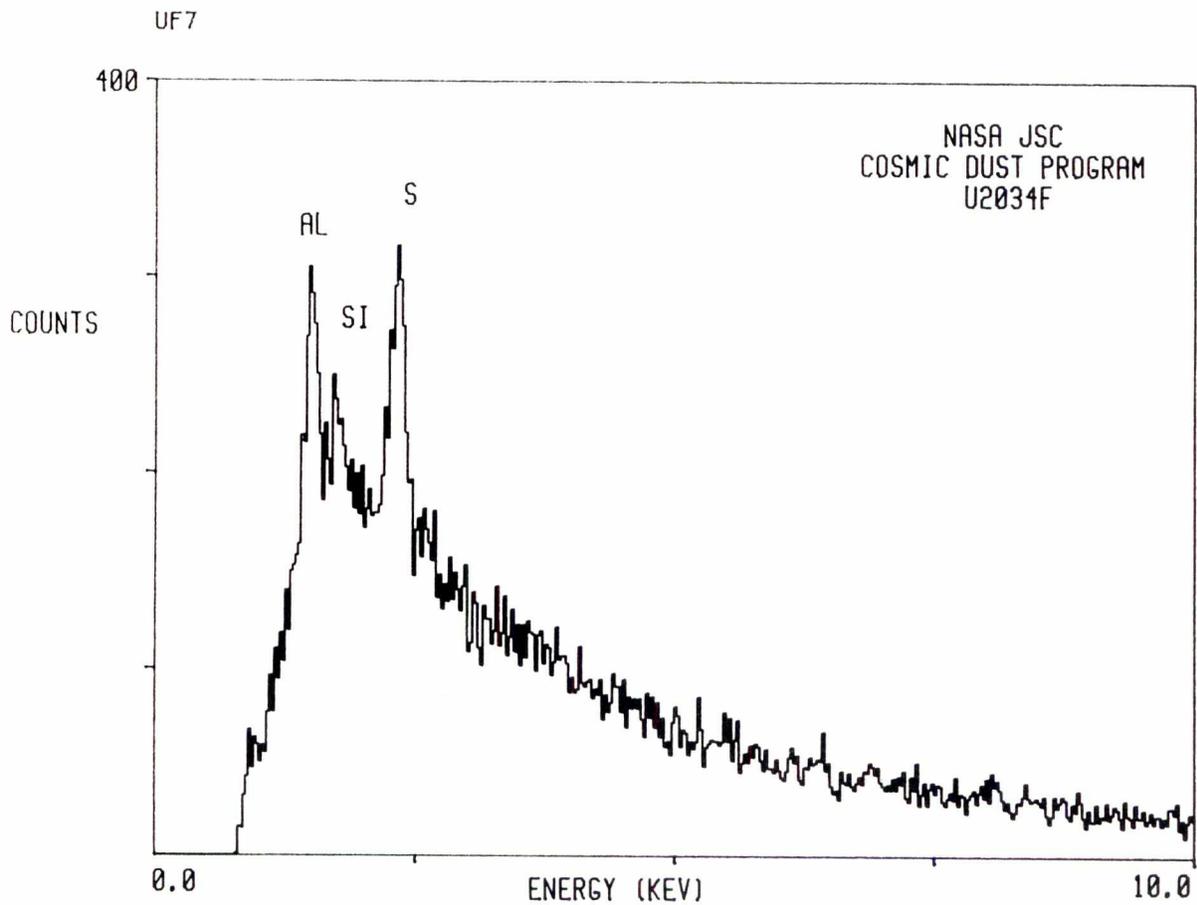


U2034 F 7

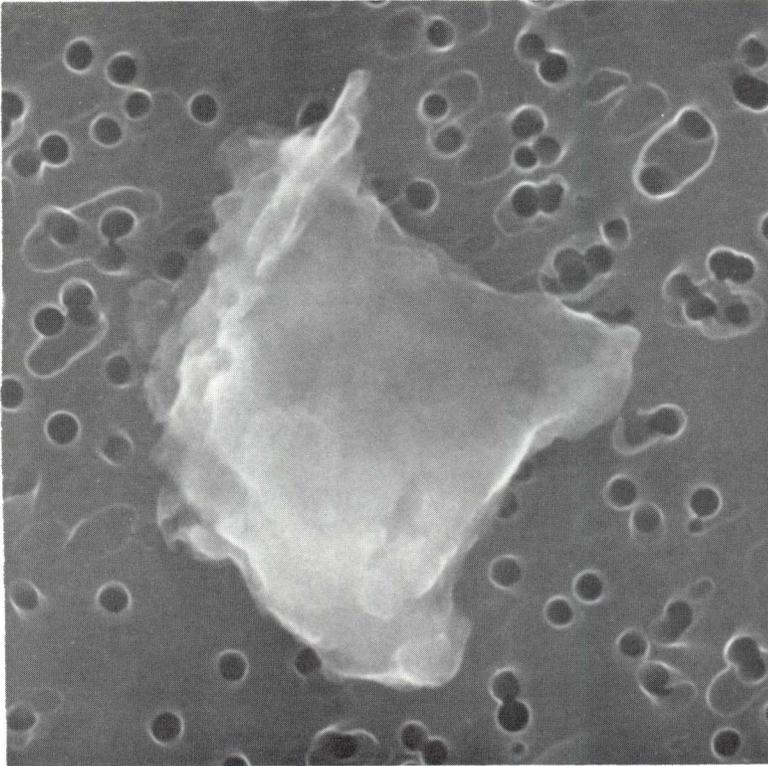


SIZE: 35x20
SHAPE: I
TRANS.: TL
COLOR: Yellow to white
LUSTER: D/SV
TYPE: TCN
COMMENTS:

S-87-46019

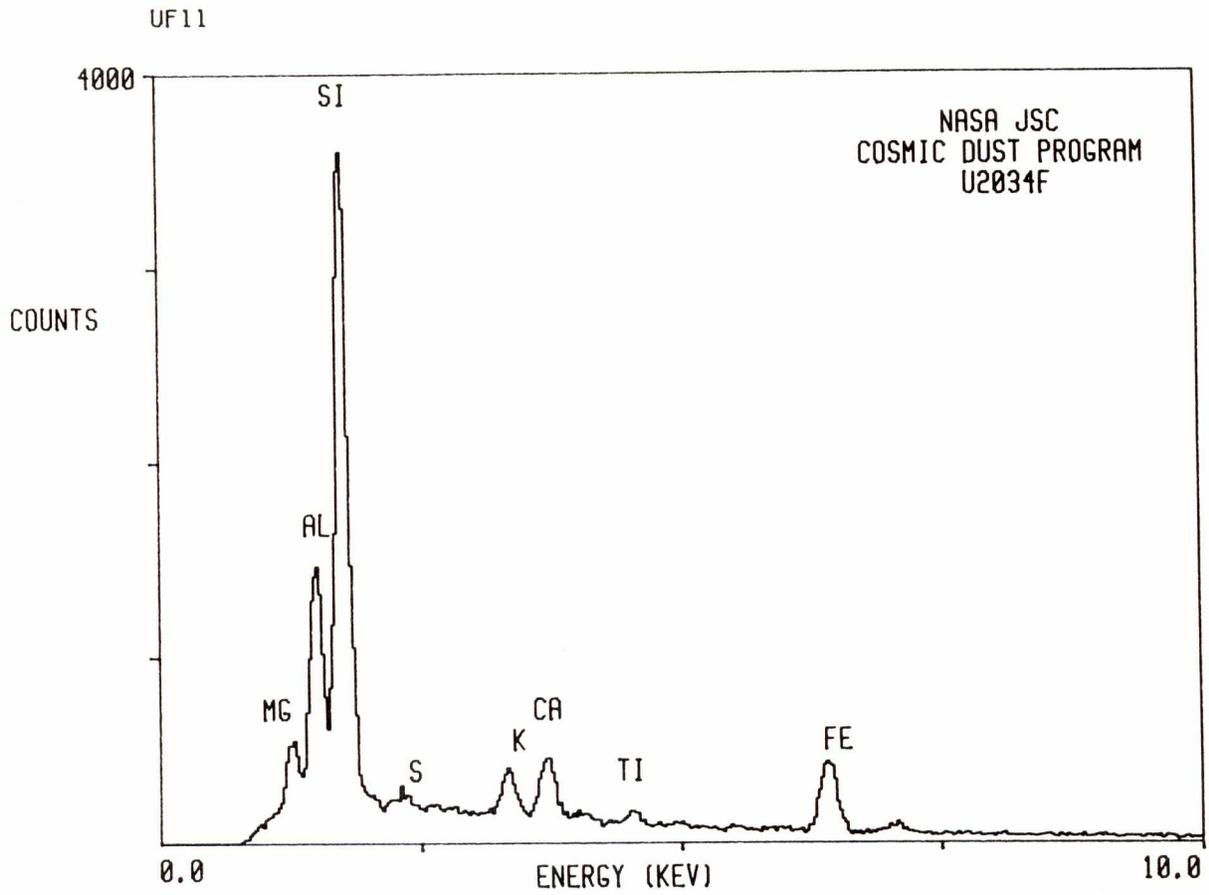


U2034 F 11

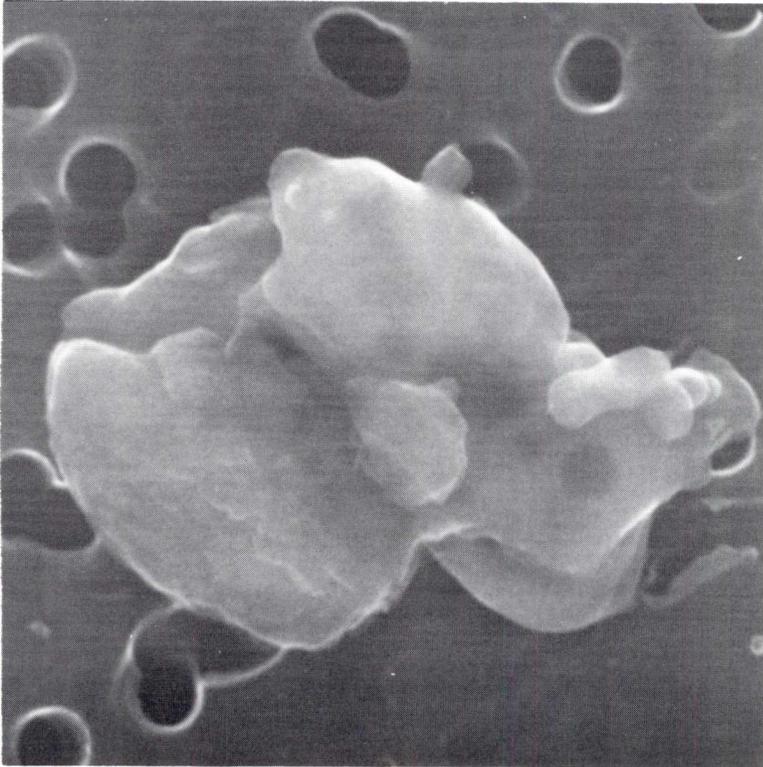


SIZE: 28x15
SHAPE: I
TRANS.: O/TL
COLOR: Black to yellow
LUSTER: D/SV
TYPE: TCN
COMMENTS:

S-87-46023

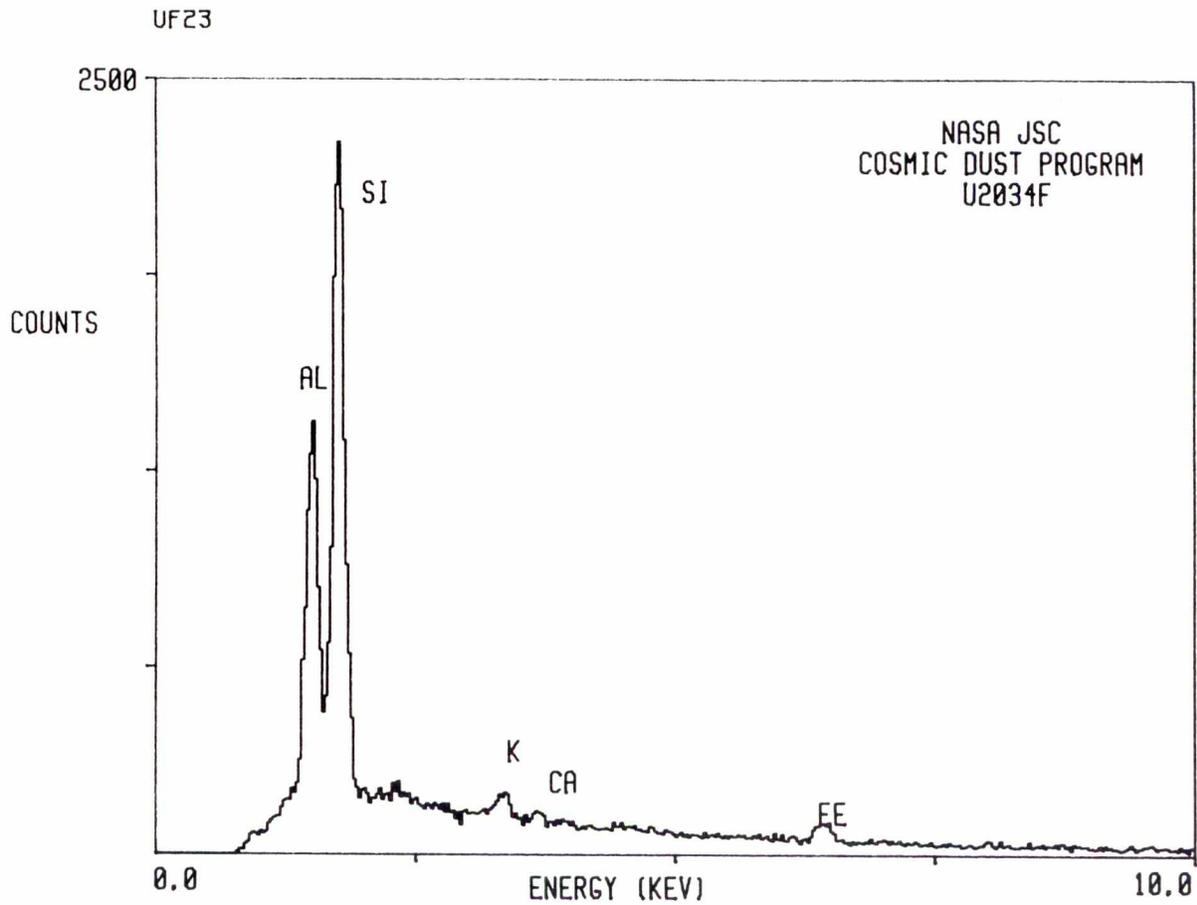


U2034 F 23

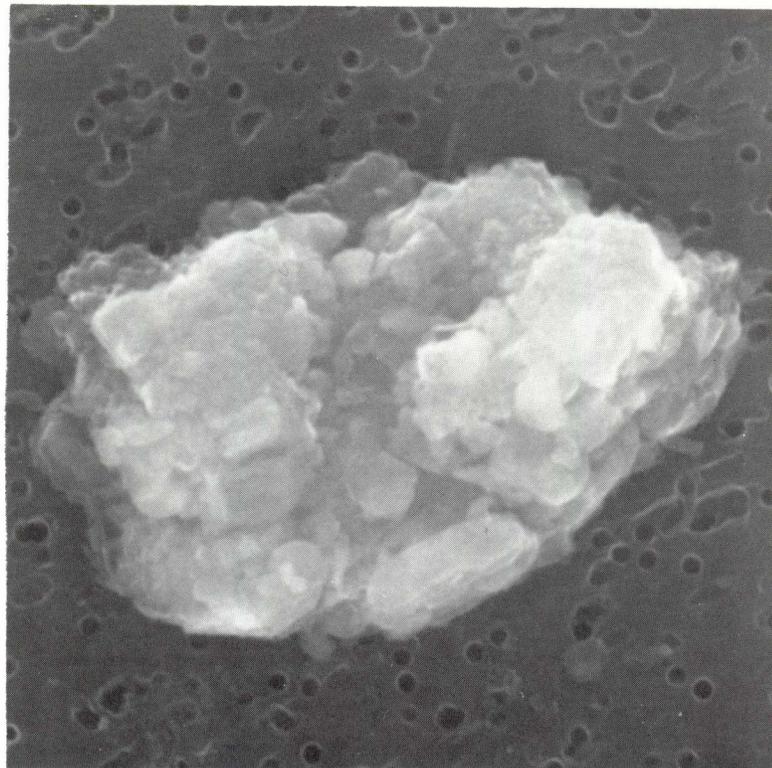


SIZE: 6
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: TCN
COMMENTS:

S-87-46031

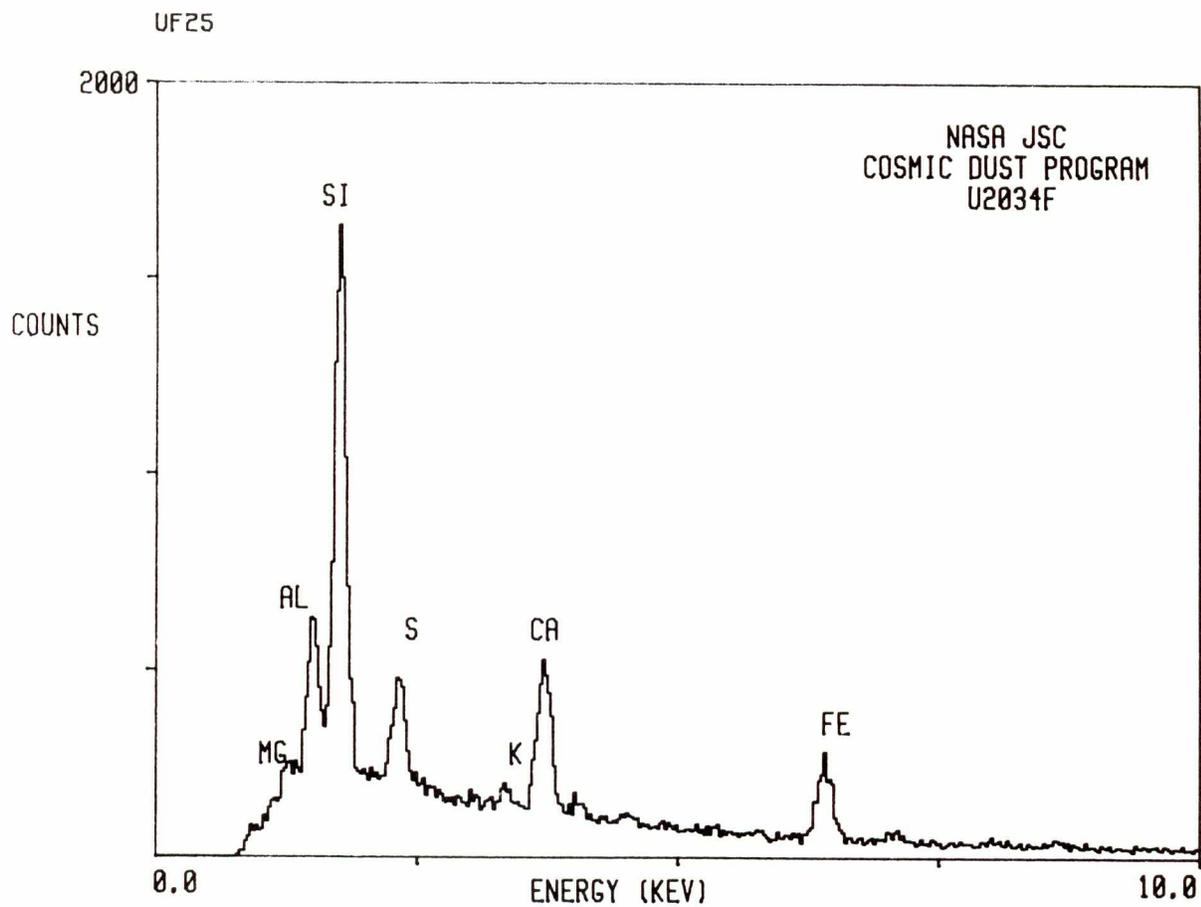


U2034 F 25



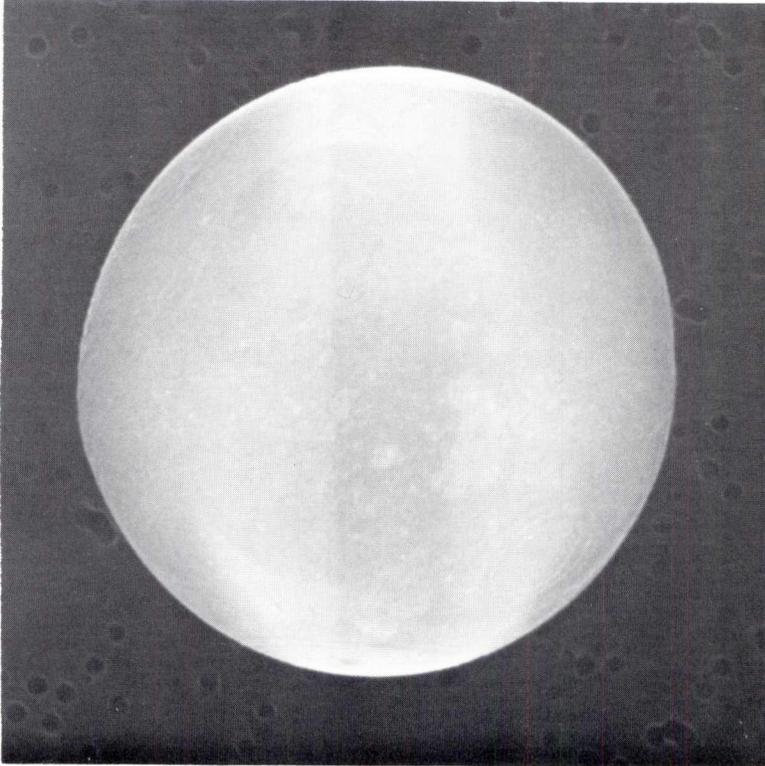
SIZE: 18x9
SHAPE: I
TRANS.: O
COLOR: Black
LUSTER: D
TYPE: TCN
COMMENTS:

S-87-46033



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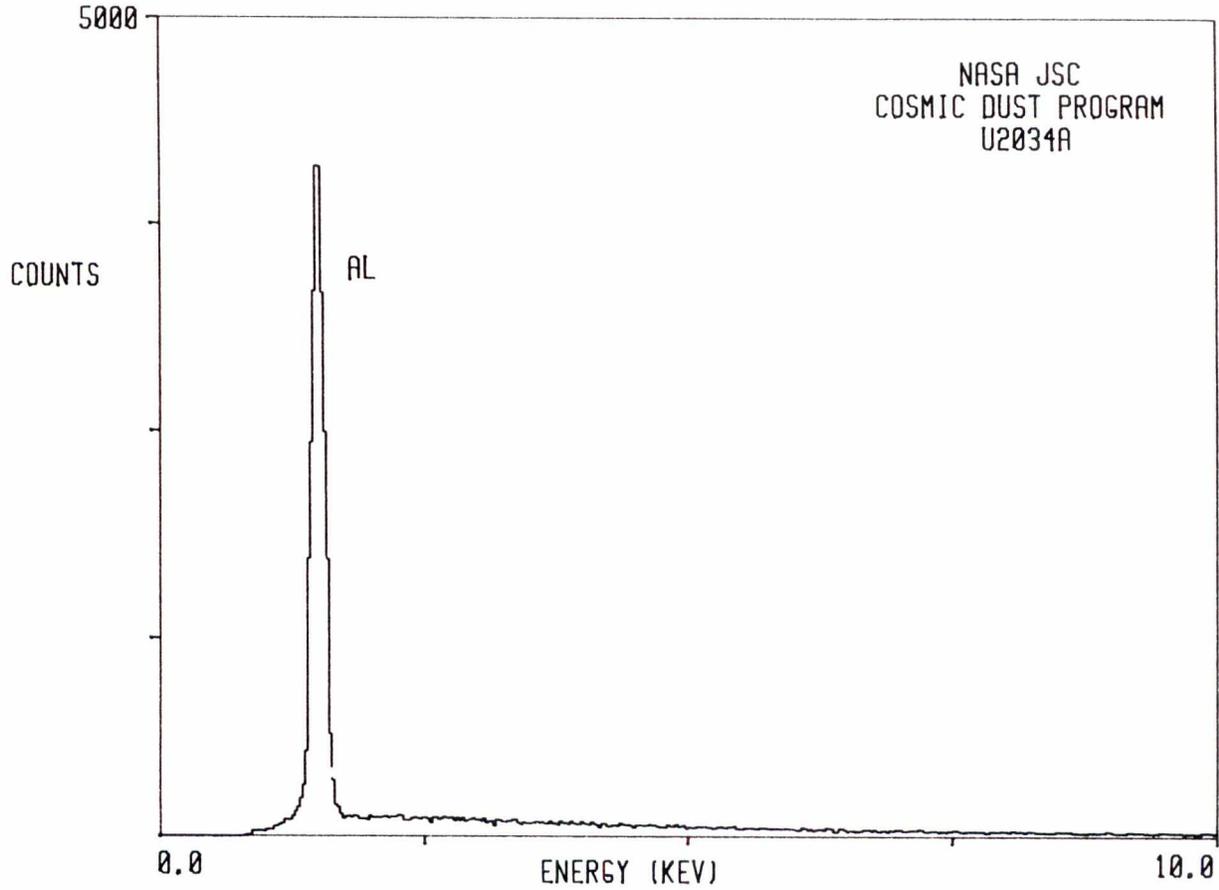
U2034 A 6



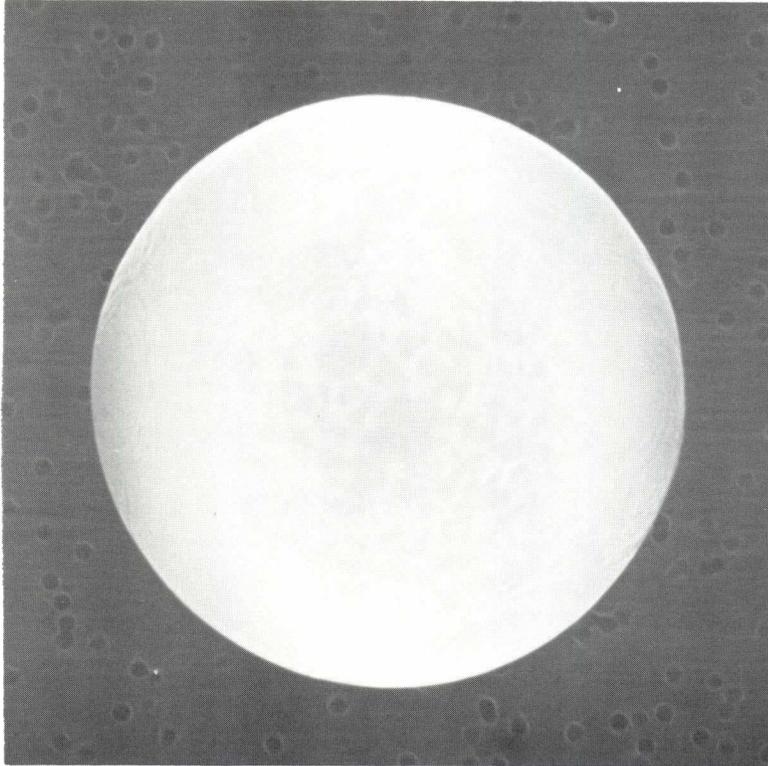
SIZE: 10
SHAPE: S
TRANS.: TL
COLOR: Yellow
LUSTER: V
TYPE: AOS
COMMENTS:

UA6

S-87-45927



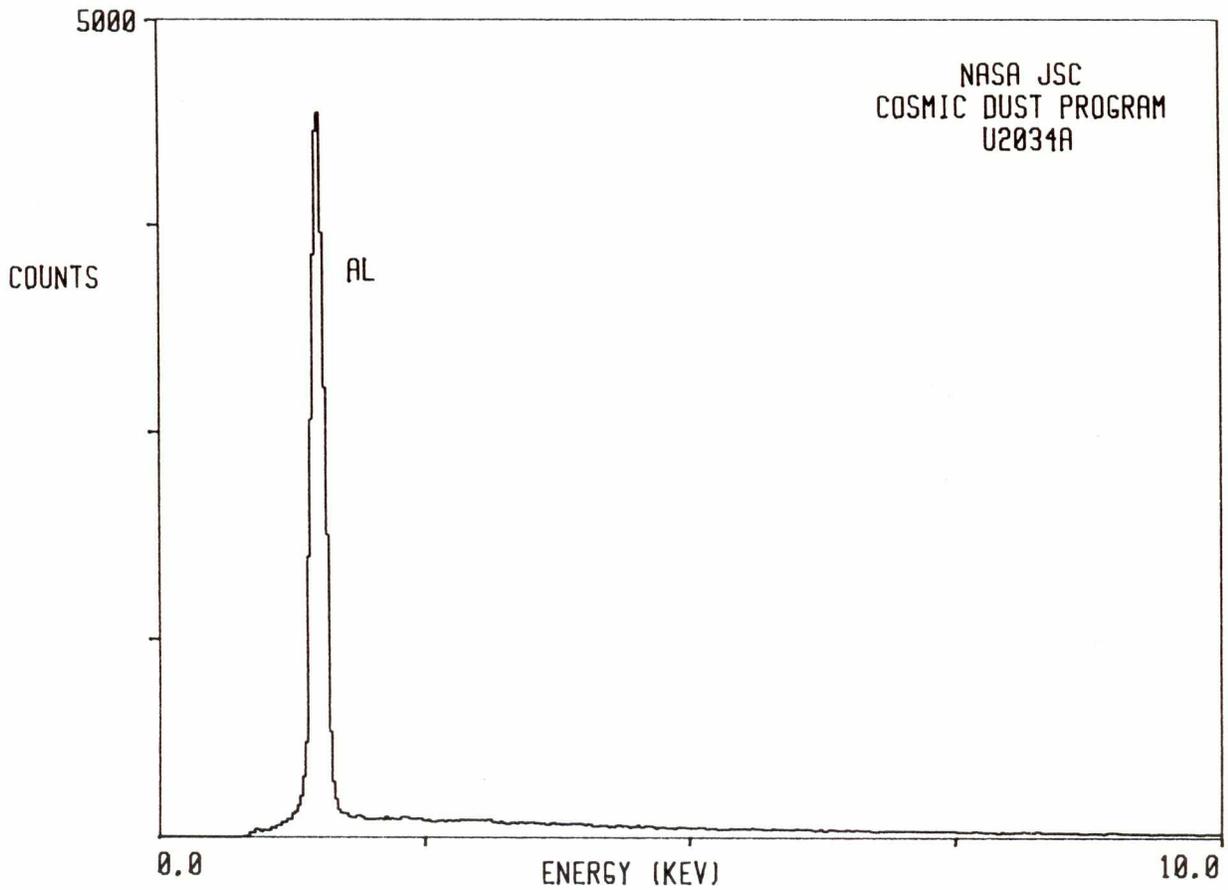
U2034 A 9



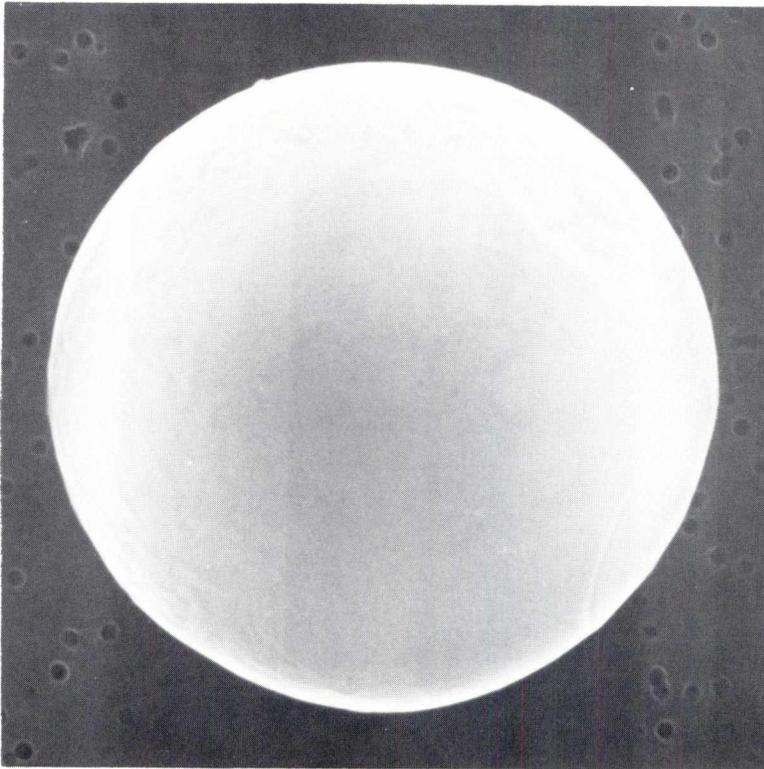
SIZE: 11
SHAPE: S
TRANS.: T
COLOR: Yellow
LUSTER: V
TYPE: AOS
COMMENTS:

UA9

S-87-45930



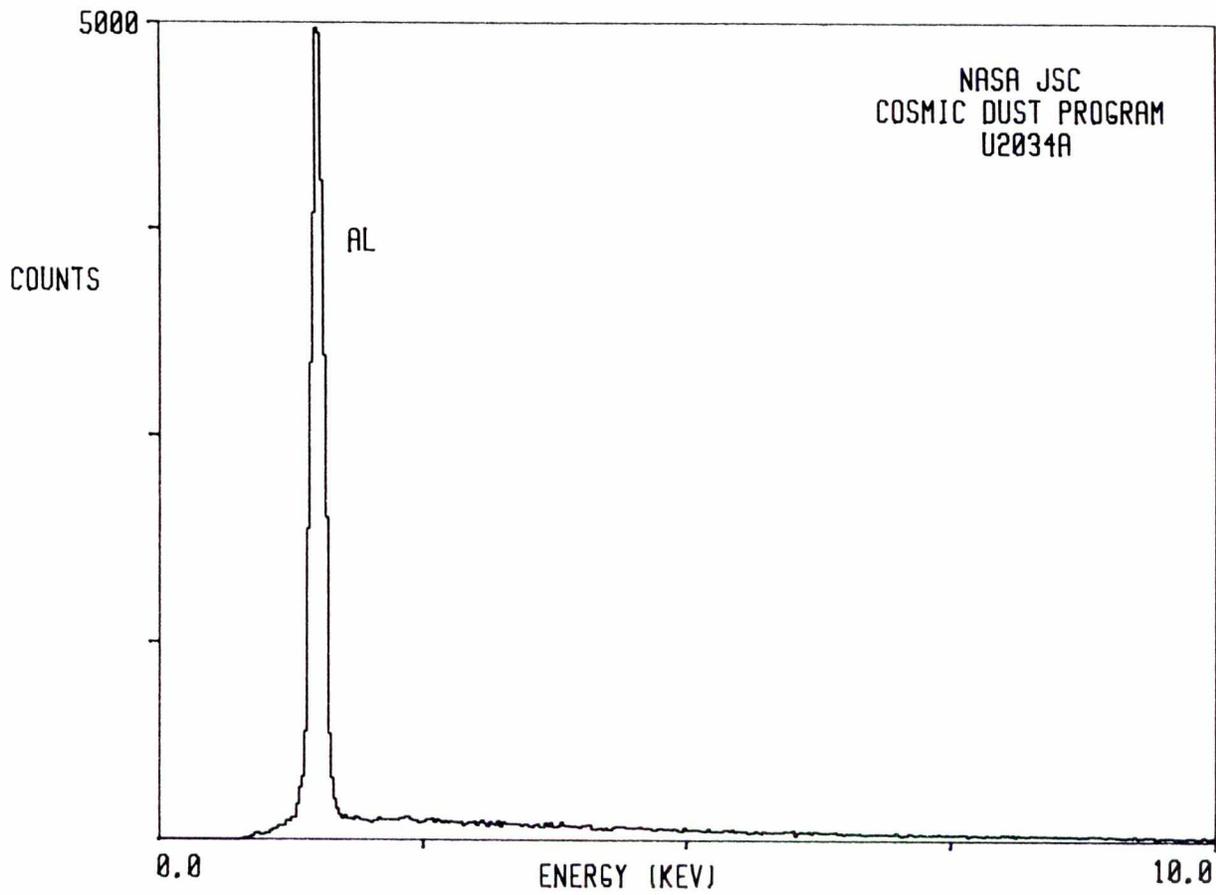
U2034 A 12



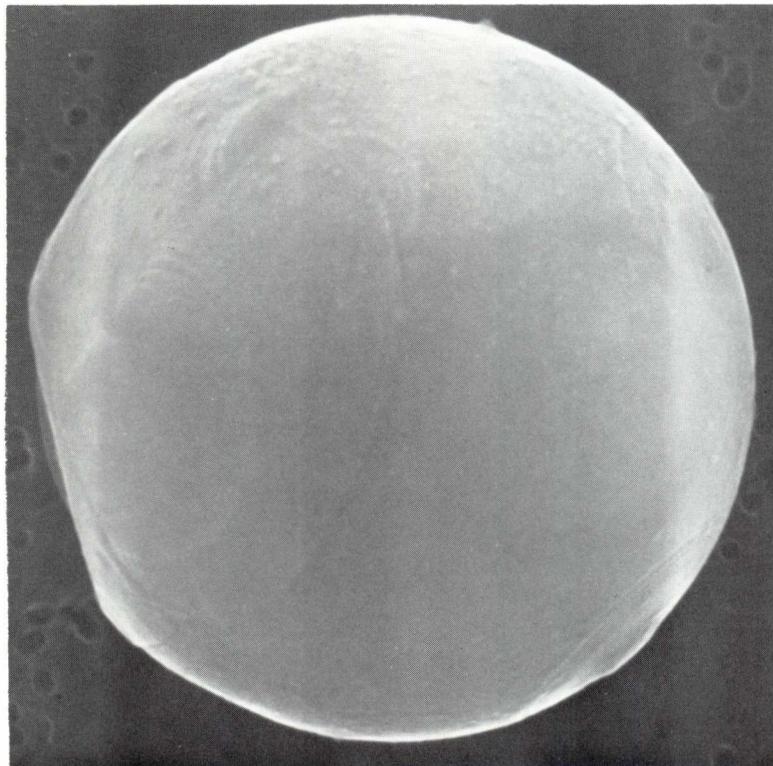
SIZE: 14
SHAPE: S
TRANS.: T
COLOR: Yellow
LUSTER: V
TYPE: AOS
COMMENTS:

UA12

S-87-45933

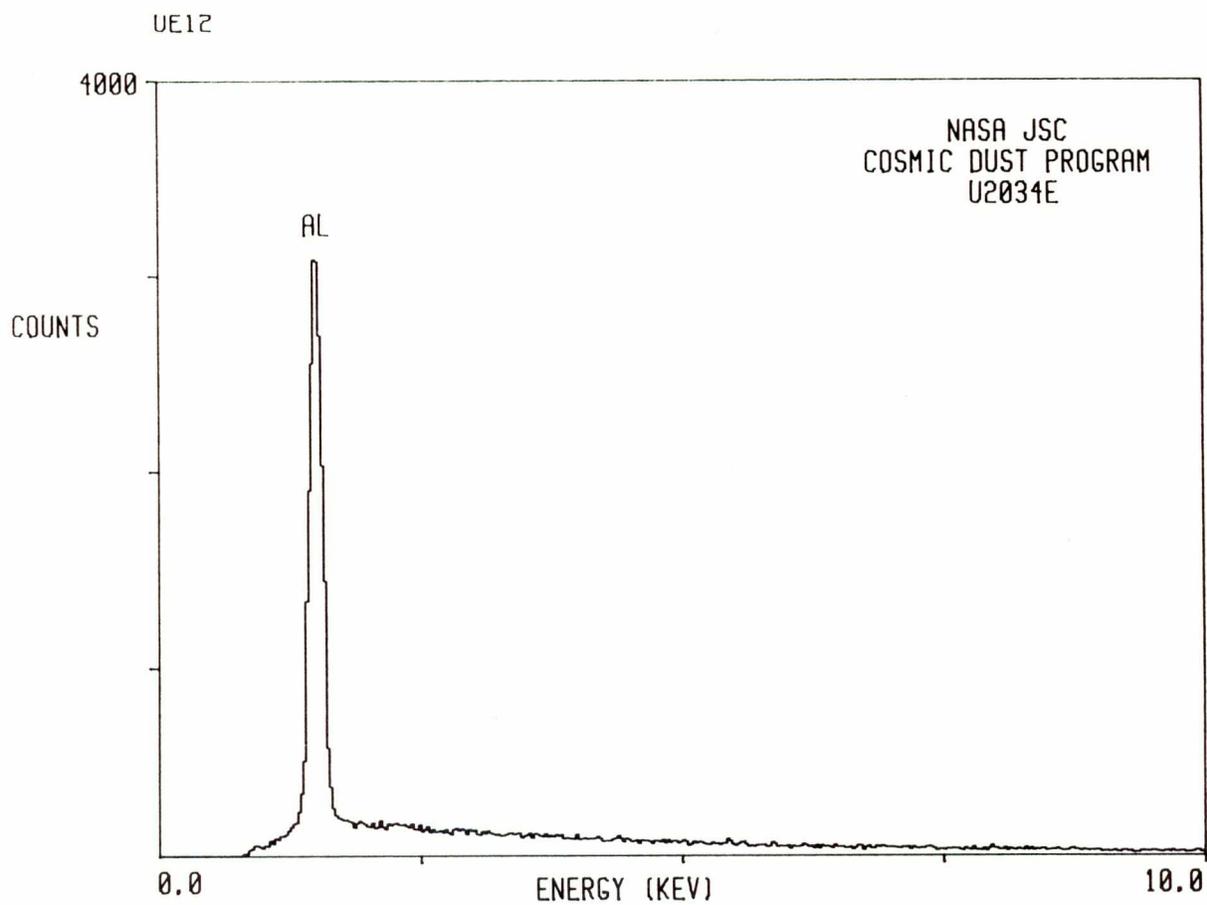


U2034 E 12

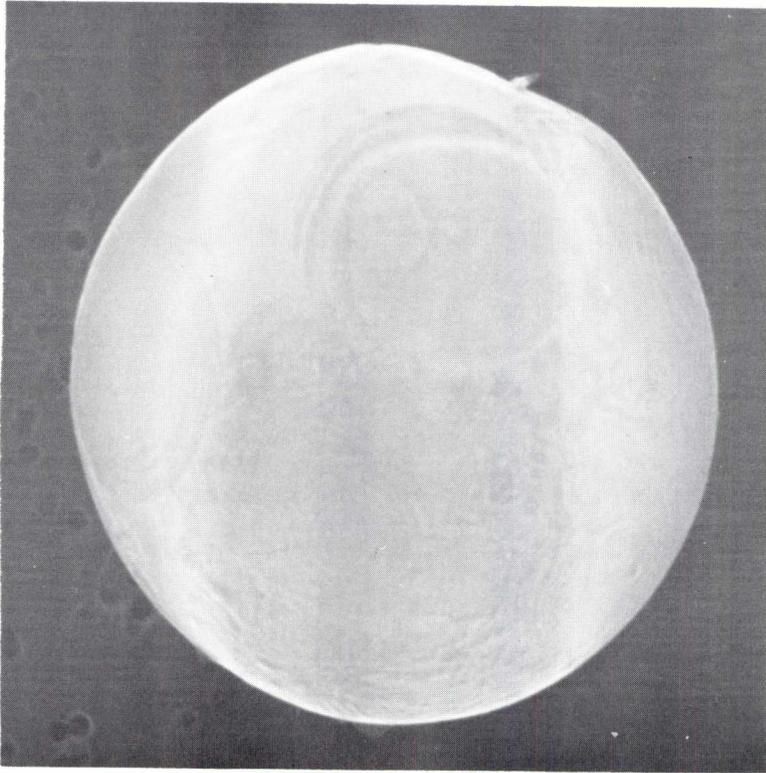


SIZE: 10
SHAPE: S
TRANS.: T
COLOR: Yellow
LUSTER: V
TYPE: AOS
COMMENTS:

S-87-46008

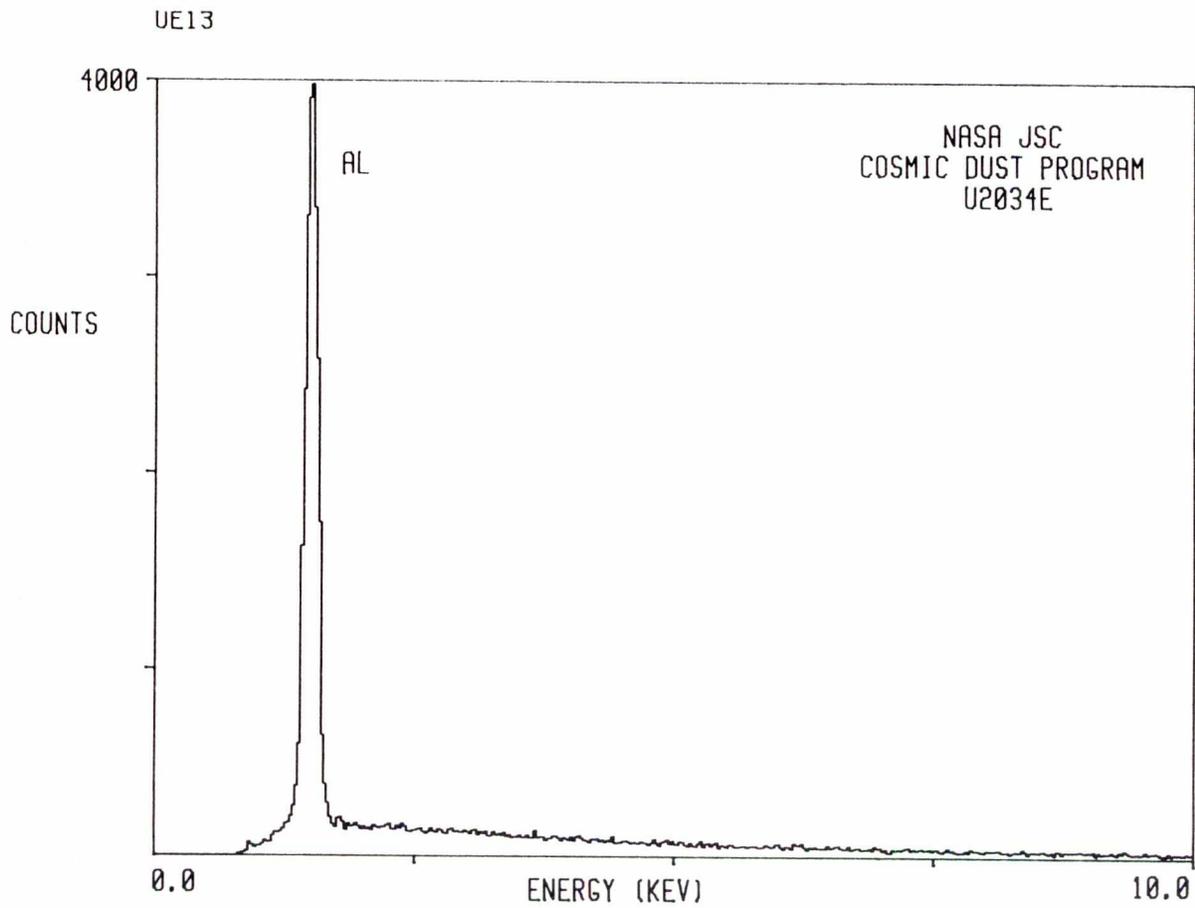


U2034 E 13

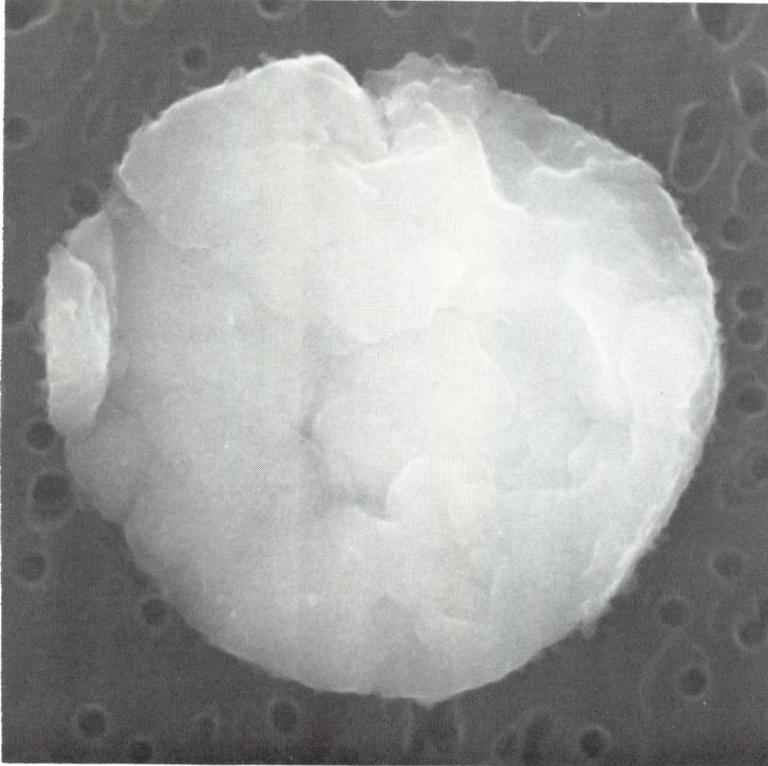


SIZE: 8
SHAPE: S
TRANS.: T
COLOR: Yellow
LUSTER: V
TYPE: AOS
COMMENTS:

S-87-46009

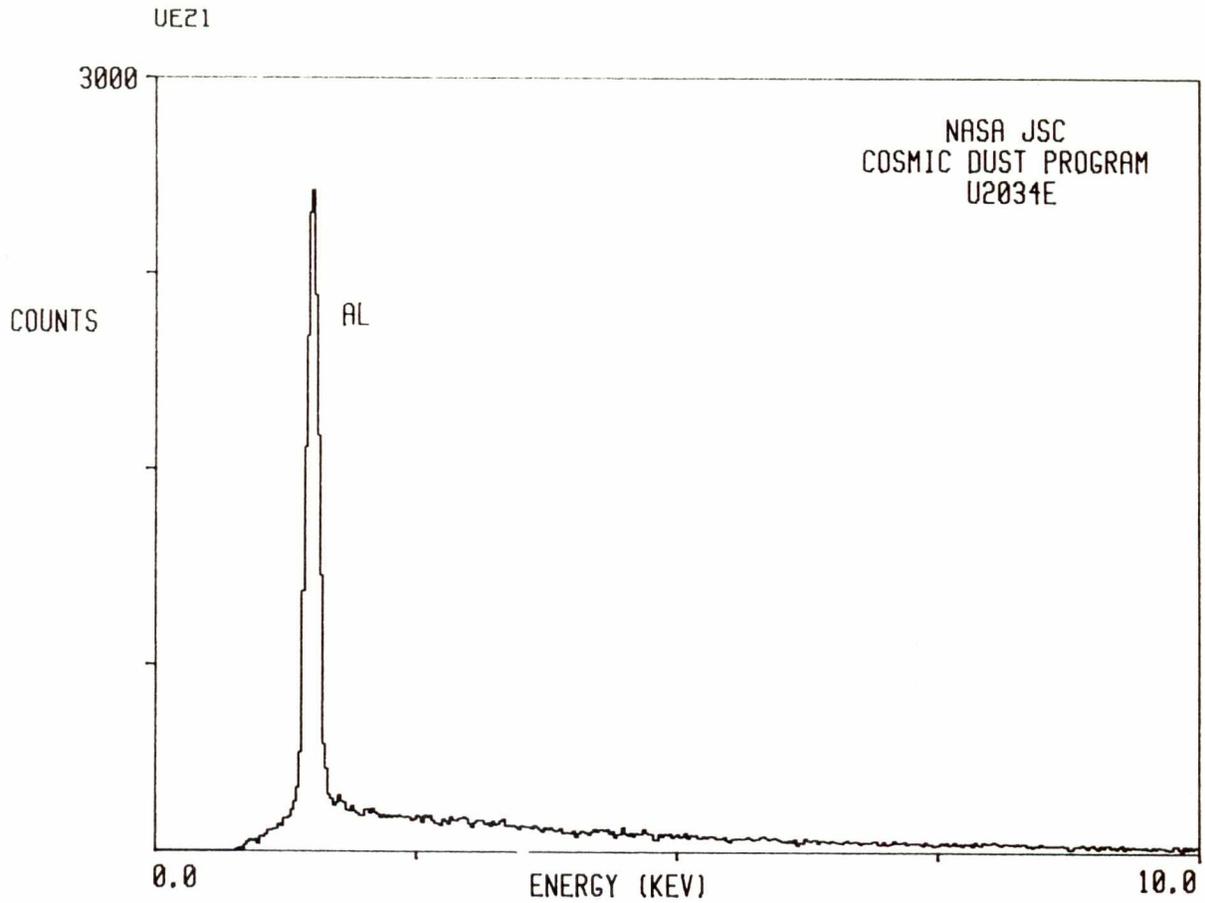


U2034 E 21

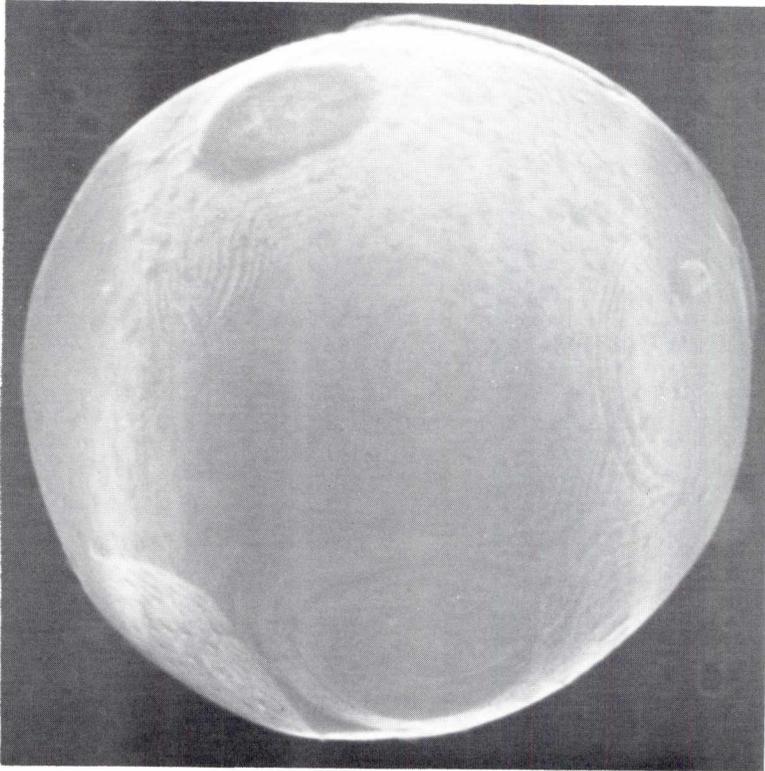


SIZE: 8
SHAPE: S
TRANS.: O/TL
COLOR: Yellow
LUSTER: SV
TYPE: AOS
COMMENTS:

S-87-46015

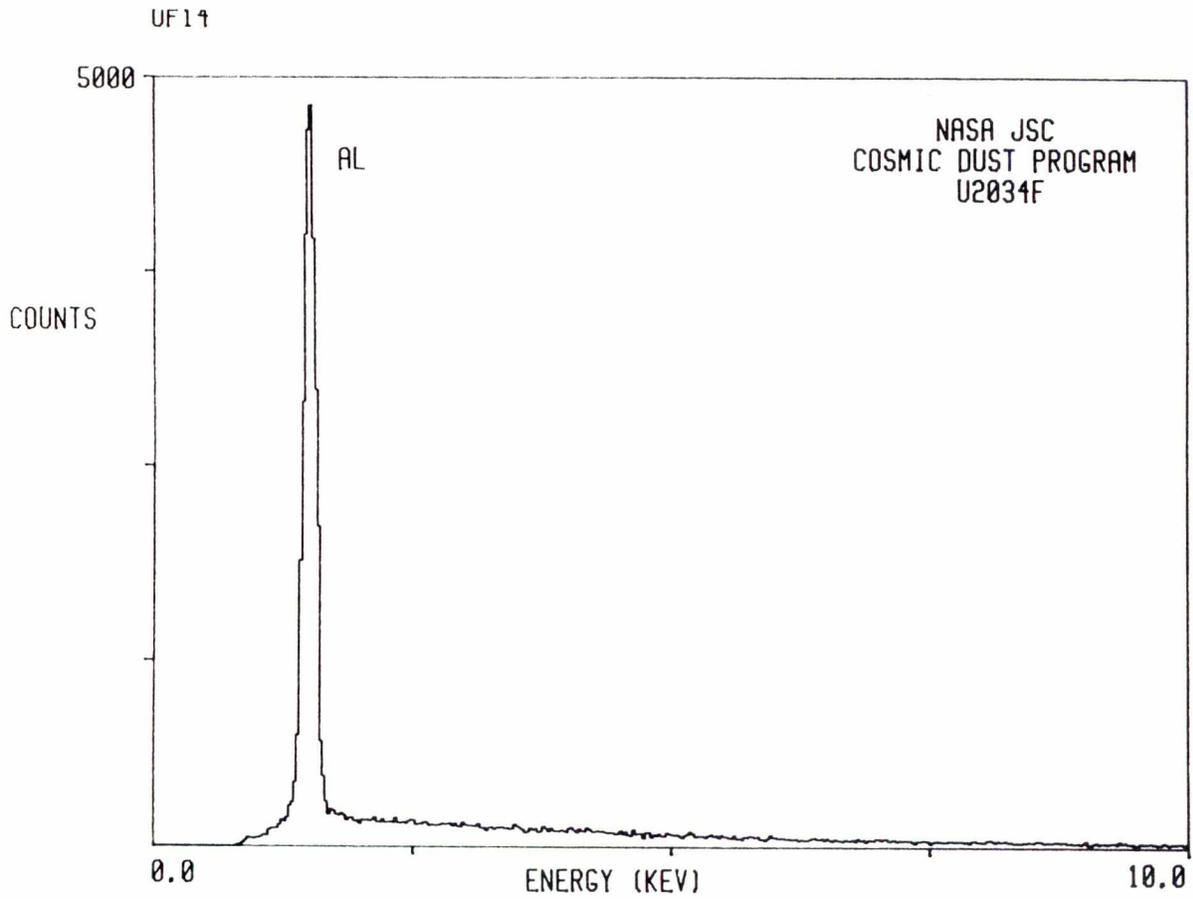


U2034 F 14

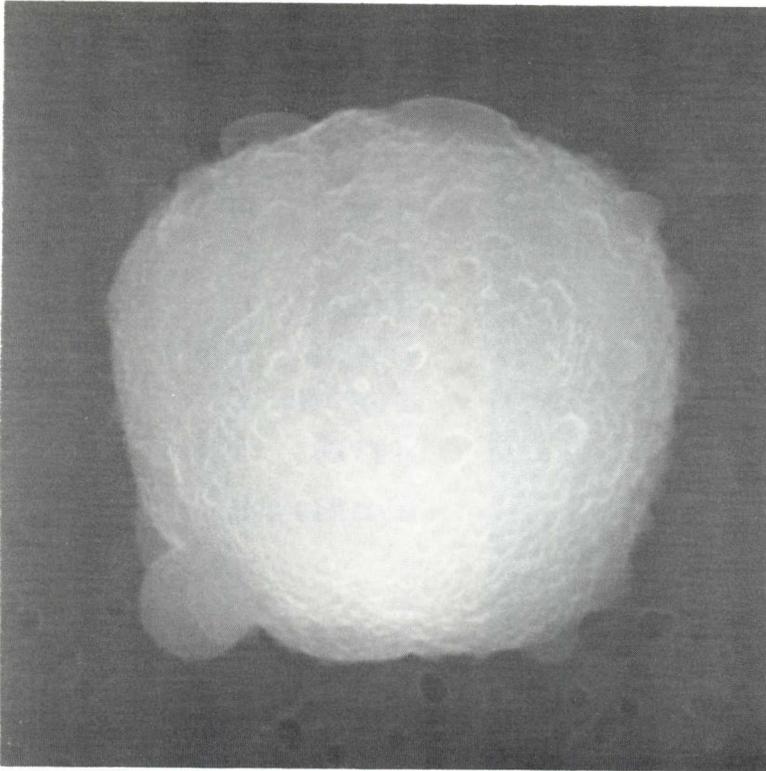


SIZE: 15
SHAPE: S
TRANS.: TL
COLOR: Brown to yellow
LUSTER: D/SV
TYPE: AOS
COMMENTS:

S-87-46025

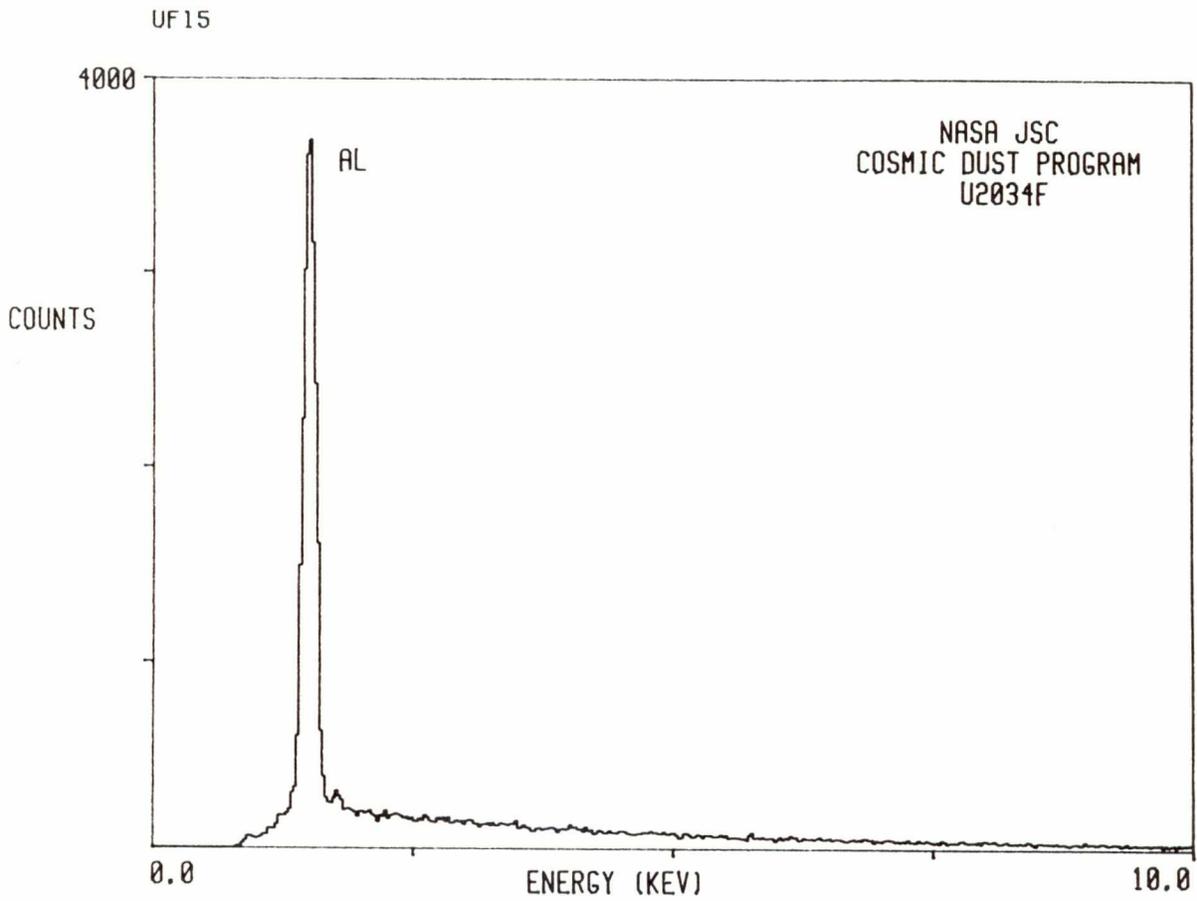


U2034 F 15

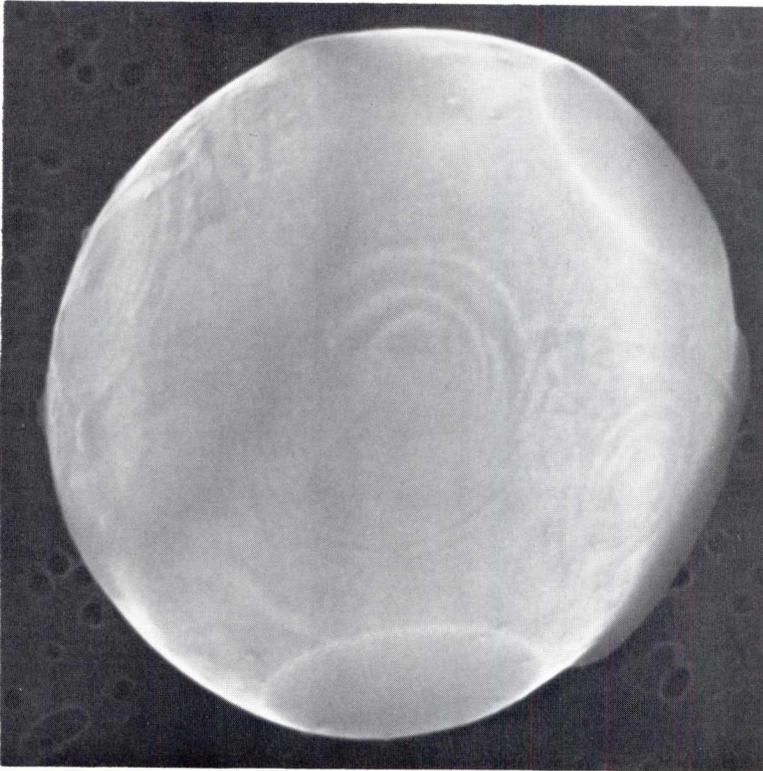


SIZE: 12
SHAPE: S
TRANS.: T
COLOR: Yellow
LUSTER: V
TYPE: AOS
COMMENTS:

S-87-46026

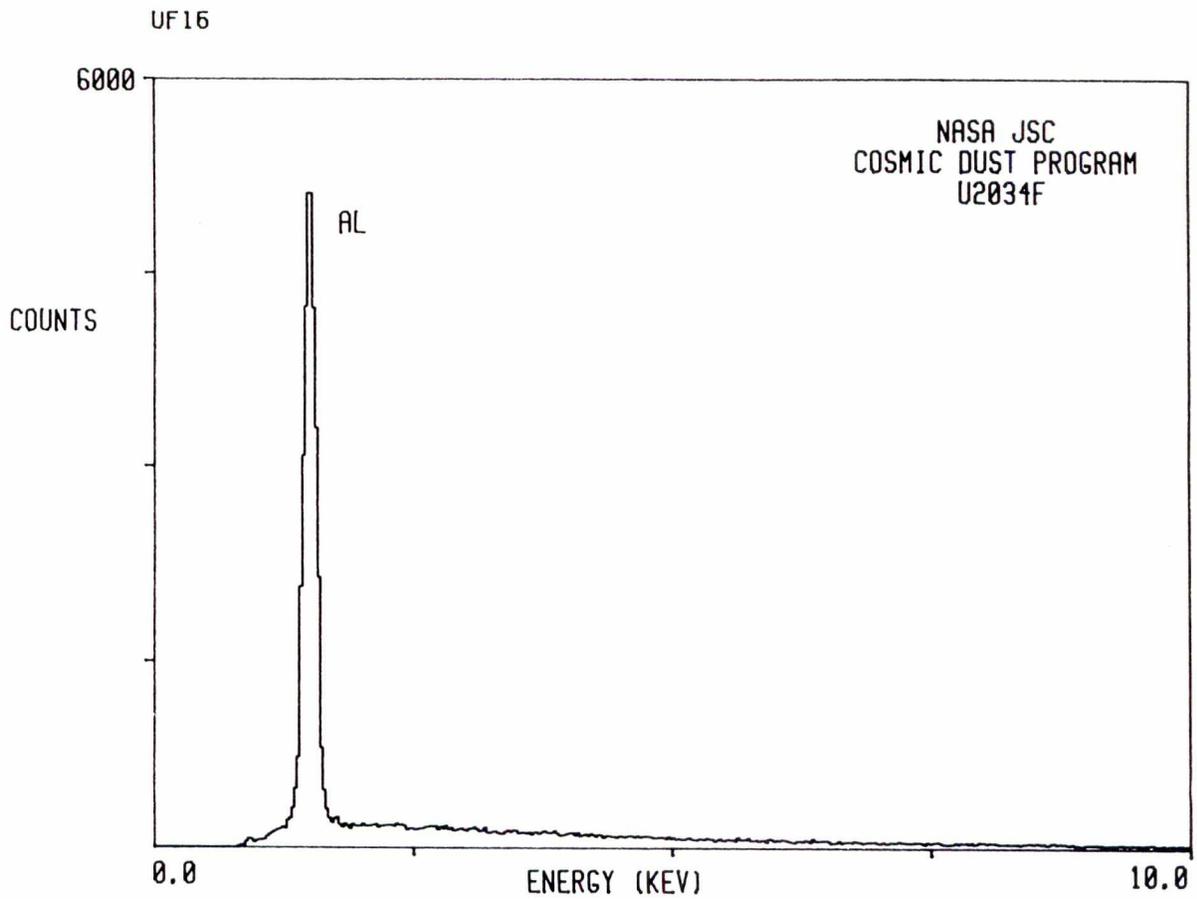


U2034 F 16

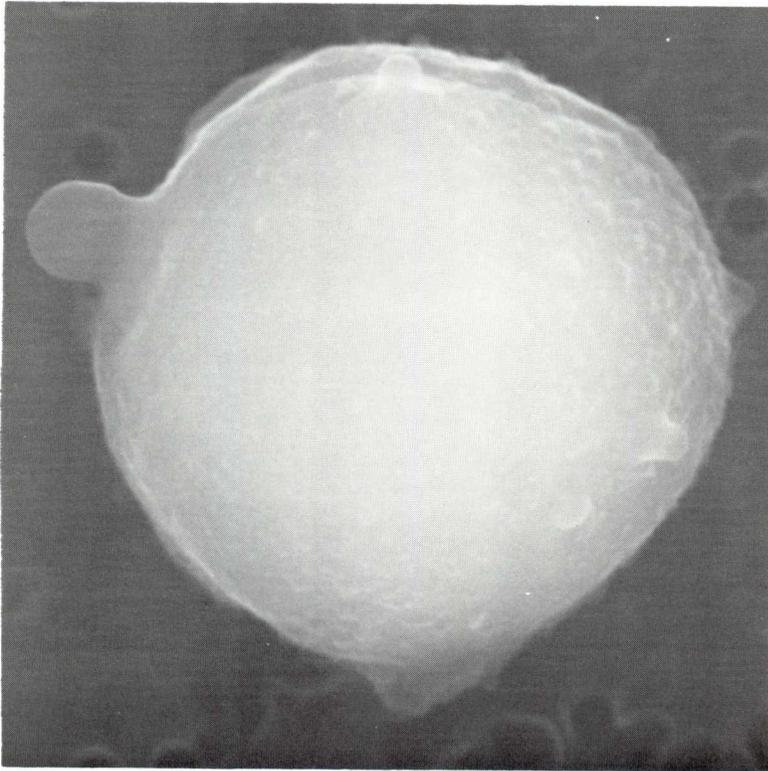


SIZE: 10
SHAPE: S
TRANS.: T
COLOR: Yellow
LUSTER: V
TYPE: AOS
COMMENTS:

S-87-46027



U2034 F 19



SIZE: 6
SHAPE: S
TRANS.: T
COLOR: Yellow
LUSTER: V
TYPE: AOS
COMMENTS:

S-87-46028

