INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

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SCHOOL ON
NON-ACCELERATOR PHYSICS
25 April - 6 May 1988

PARTICLE PHYSICS WITH BALLOONS SATELLITES AND SPACE STATIONS (2)

by

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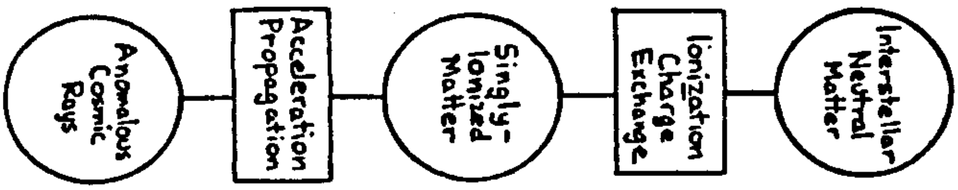
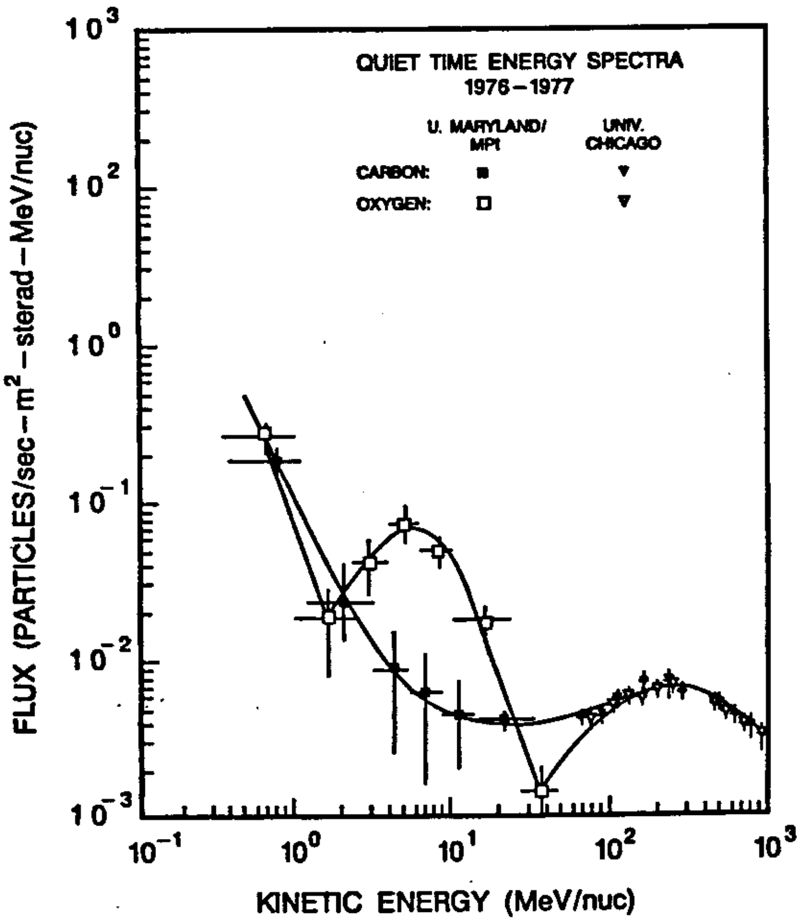


EXAMPLES OF ENERGY SPECTRA DURING PERIODS OF MINIMUM SOLAR ACTIVITY

- THE ENERGY SPECTRA FOR CARBON IS APPARENTLY THE SUPERPOSITION OF TWO COMPONENTS:
  - RAPIDLY FALLING SPECTRA BELOW ABOUT 10 MeV/NUCLEON OF SOLAR OR INTERPLANETARY ORIGIN
  - RAPIDLY RISING SPECTRA ABOVE ABOUT 10 MeV/NUCLEON OF SOLAR-MODULATED GALACTIC COSMIC RAYS
- THE ENERGY SPECTRA FOR OXYGEN IS APPARENTLY THE SUPERPOSITION OF THREE COMPONENTS:
  - THE FALLING SOLAR OR INTERPLANETARY COMPONENT
  - THE RISING SOLAR-MODULATED GALACTIC COMPONENT
  - THE "ANOMALOUS" COMPONENT GIVING A PEAK NEAR 10 MeV/NUCLEON



O THE ANOMALOUS COMPONENT IS STRONGLY EVIDENT IN THE SPECTRA OF HE, N, O, AND NE.

O SHORTLY AFTER THIS WAS DISCOVERED, IT WAS RECOGNIZED THAT THE ELEMENTAL SPECTRA CONTAINING THE ANOMALOUS COMPONENT ALL HAVE ONE THING IN COMMON:

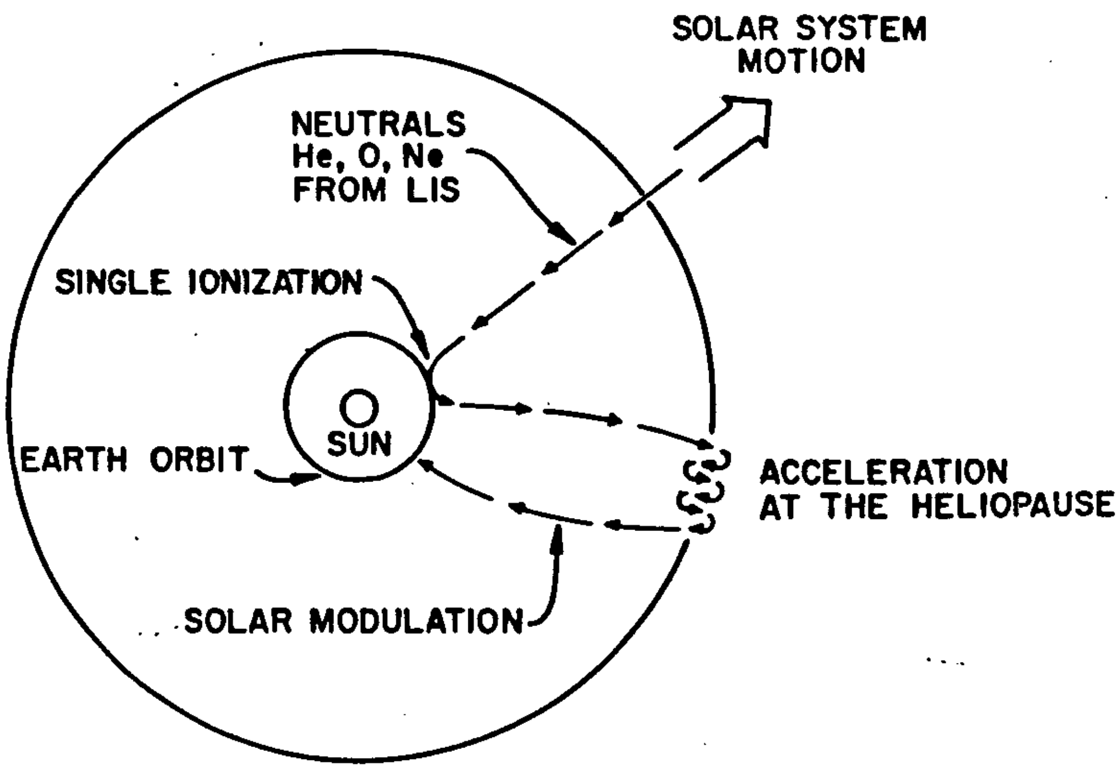
- THEIR FIRST IONIZATION POTENTIAL IS EQUAL TO OR GREATER THAN HYDROGEN.

CURRENT THEORY FOR ORIGIN OF THE ANOMALOUS COMPONENT

- INTERSTELLAR NEUTRAL ATOMS ARE SWEPT INTO THE HELIOSPHERE BY THE MOTION OF THE SUN THROUGH THE LOCAL INTERSTELLAR GAS

- THESE ATOMS ARE SINGLY-IONIZED IN THE INNER SOLAR SYSTEM
  - BY PHOTOELECTRIC INTERACTIONS WITH UV LIGHT FROM THE SUN
  - BY CHARGE EXCHANGE WITH HYDROGEN ATOMS IN THE SOLAR WIND

- THE IONS ARE THEN CARRIED BY THE SOLAR WIND TO THE OUTER HELIOSPHERE, PROBABLY TO THE REGION OF THE HELIOPAUSE



CURRENT THEORY FOR ORIGIN OF THE ANOMALOUS COMPONENT (CONT'D)

- THE IONS ARE ACCELERATED TO 10's OF MeV BY INTERACTIONS WITH THE SOLAR WIND-INTERSTELLR MEDIUM BOUNDARY SHOCK
- SOME OF THE IONS ARE PROJECTED BACK TO THE INNER HELIOSPHERE
- SINGLY-IONIZED ATOMS ARE CONSIDERABLY LESS AFFECTED BY SOLAR MODULATION THAN FULLY-IONIZED GALACTIC COSMIC RAYS
  - SINGLY-IONIZED IONS WITH ENERGIES BELOW 10 MeV CAN REACH EARTH AND BE OBSERVED WITH SPACECRAFT DETECTORS
  - FULLY-IONIZED IONS AT SUCH LOW ENERGIES ARE VERY INEFFICIENT IN MOVING UPSTREAM AGAINST THE SOLAR WIND

0 IF THIS THEORY IS CORRECT, THE ANOMALOUS COMPONENT IS A SAMPLE OF THE VERY LOCAL INTERSTELLAR MEDIUM, AND ITS ELEMENTAL AND ISOTOPIC COMPOSITION COULD BE MEASURED. BY COMPARING THE COMPOSITION OF THE LOCAL INTERSTELLAR MEDIUM WITH THAT OF OTHER SAMPLES OF MATTER FROM OUR GALAXY, SCIENTISTS WILL BE ABLE TO LOOK AT GALACTIC EVOLUTION EFFECTS.

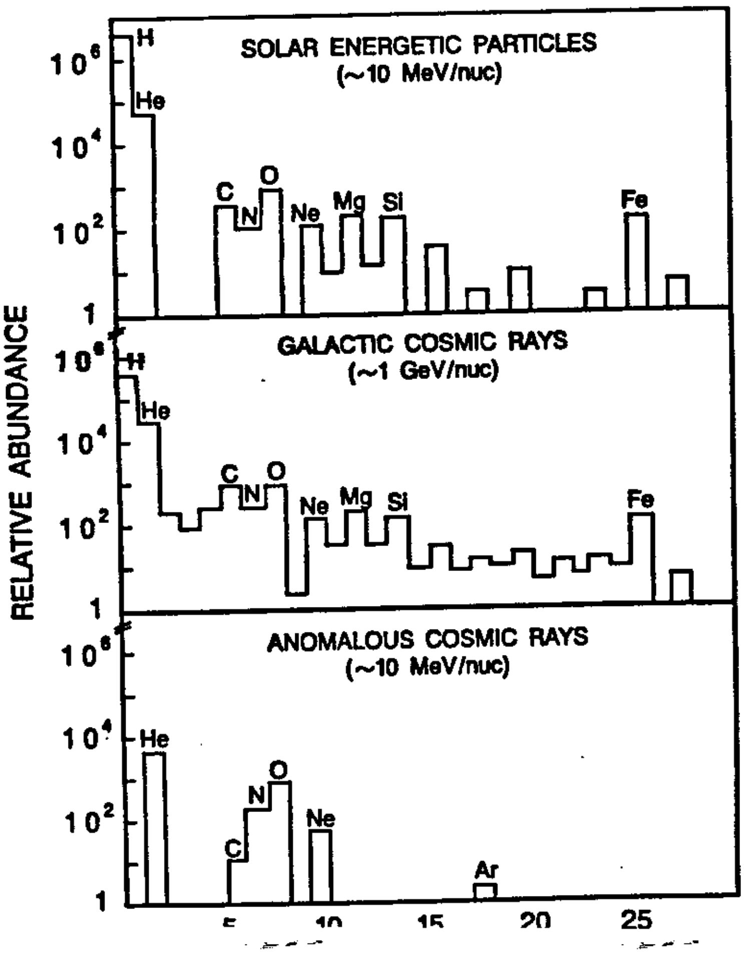
0 IF THE THEORY IS CORRECT, IT ALSO OFFERS VALUABLE INSIGHT INTO SOLAR MODULATION, INTERPLANETARY PROPAGATION, AND THE NATURE OF THE HELIOSPHERIC BOUNDARY

0 THERE ARE TWO KEY PREDICTIONS OF THE THEORY:

- THE ELEMENTAL COMPOSITION OF ANOMALOUS COMPONENT WILL REFLECT THE COMPOSITION OF THE NEUTRAL COMPONENT OF LOCAL INTERSTELLAR GAS
- THESE IONS WILL ALL BE SINGLY IONIZED

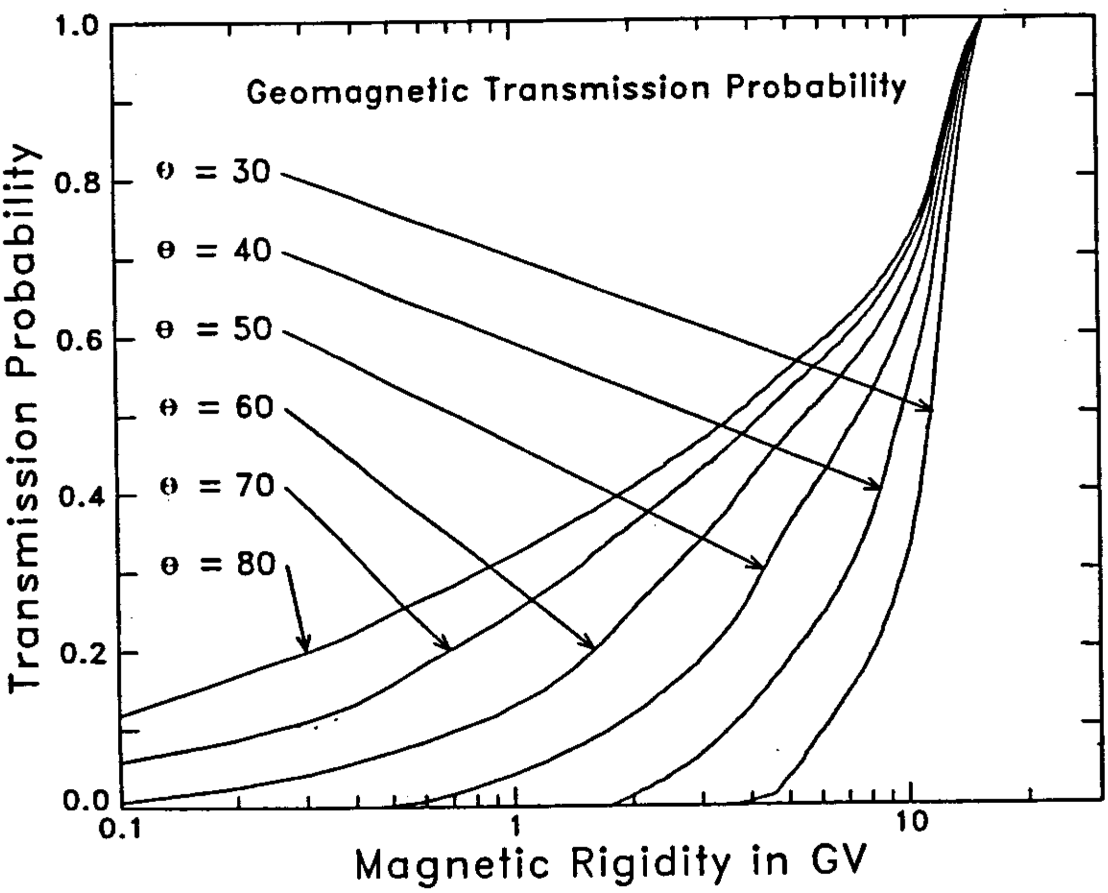
ELEMENTAL COMPOSITION OF THE ANOMALOUS COMPONENT

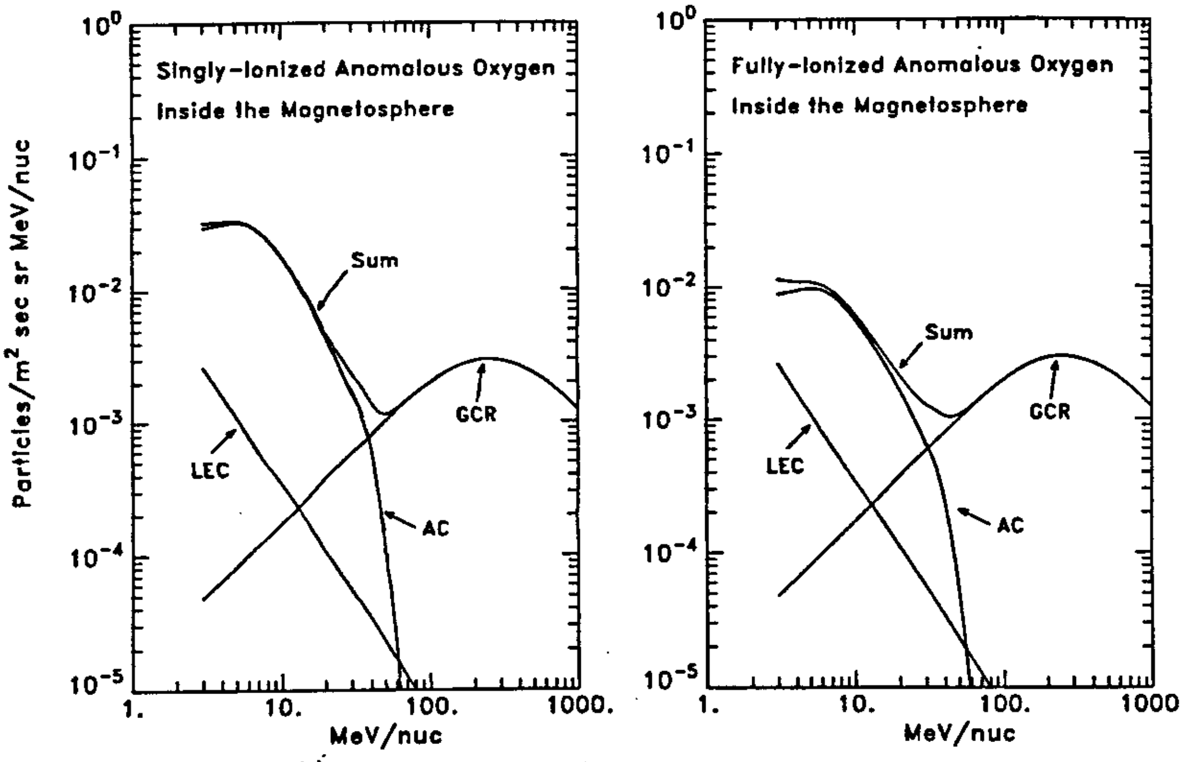
- THE COMPOSITION OF THE "ANOMALOUS COMPONENT" IS ANOMALOUS
  - COMPARED TO GALACTIC C. R. & SOLAR ENERGETIC PARTICLES
- THE CHEMICAL COMPOSITON OF THE ANOMALOUS COMPONENT IS
  - SIMILAR TO THE COMPOSITION OF INTERSTELLAR GAS
- THE ELEMENTS N, O, Ne, AND Ar ARE MOSTLY NEUTRAL IN THE ISM
  - THEIR SPECTRA DOMINATE THE ANOMALOUS COMP0NENT
- THE ANOMALOUS COMPONENT IS PRESENT IN HYDROGEN, BUT ITS ABUNDANCE IS STILL UNCERTAIN
- CARBON HAS A LOW-LEVEL ANOMALOUS COMPONENT, WHICH REFLECTS THE SMALL FRACTION OF NEUTRAL CARBON IN THE ISM

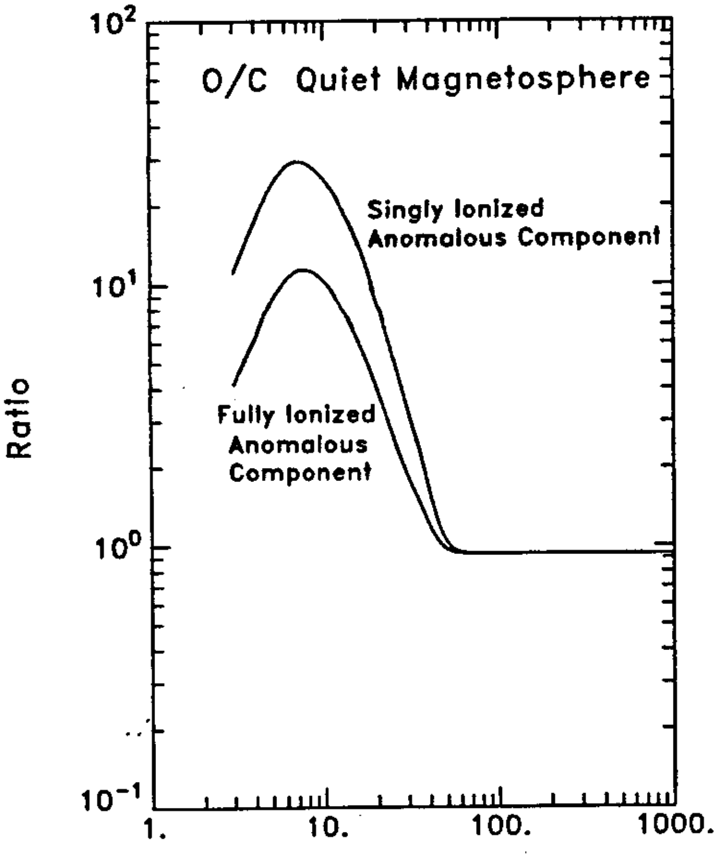


USE OF THE EARTH'S MAGNETIC FIELD AS ANALYZING MAGNET

- ORBIT-AVERAGED TRANSMISSION PROBABILITIES CAN BE CALCULATED FOR PARTICLE DETECTORS IN ANY SPECIFIED ORBIT BY:
  - DETERMINING THE GEOMAGNETIC CUTOFF ALONG THE ORBIT
  - CALCULATING PARTICLE TRAJECTORIES THAT REACH DETECTORS
- THE TRANSMISSION PROBABILITIES ARE FUNCTIONS OF INCIDENT ANGLE AND PARTICLE RIGIDITY (MOMENTUM/CHARGE)
- AS AN EXAMPLE, THE ENERGY SPECTRA OF OXYGEN REACHING COSMOS-1649 AT SOLAR QUIET-TIMES HAVE BEEN ESTIMATED
  - BELOW 10 MeV THE SINGLE-IONIZED AND FULLY-IONIZED FLUX LEVELS DIFFER BY A FACTOR OF ABOUT 3
- THE OXYGEN/CARBON RATIO BELOW 10 MeV AT QUIET-TIMES DEPENDS STRONGLY ON THE IONIZATION STATE (SINGLY OR FULLY IONIZED)

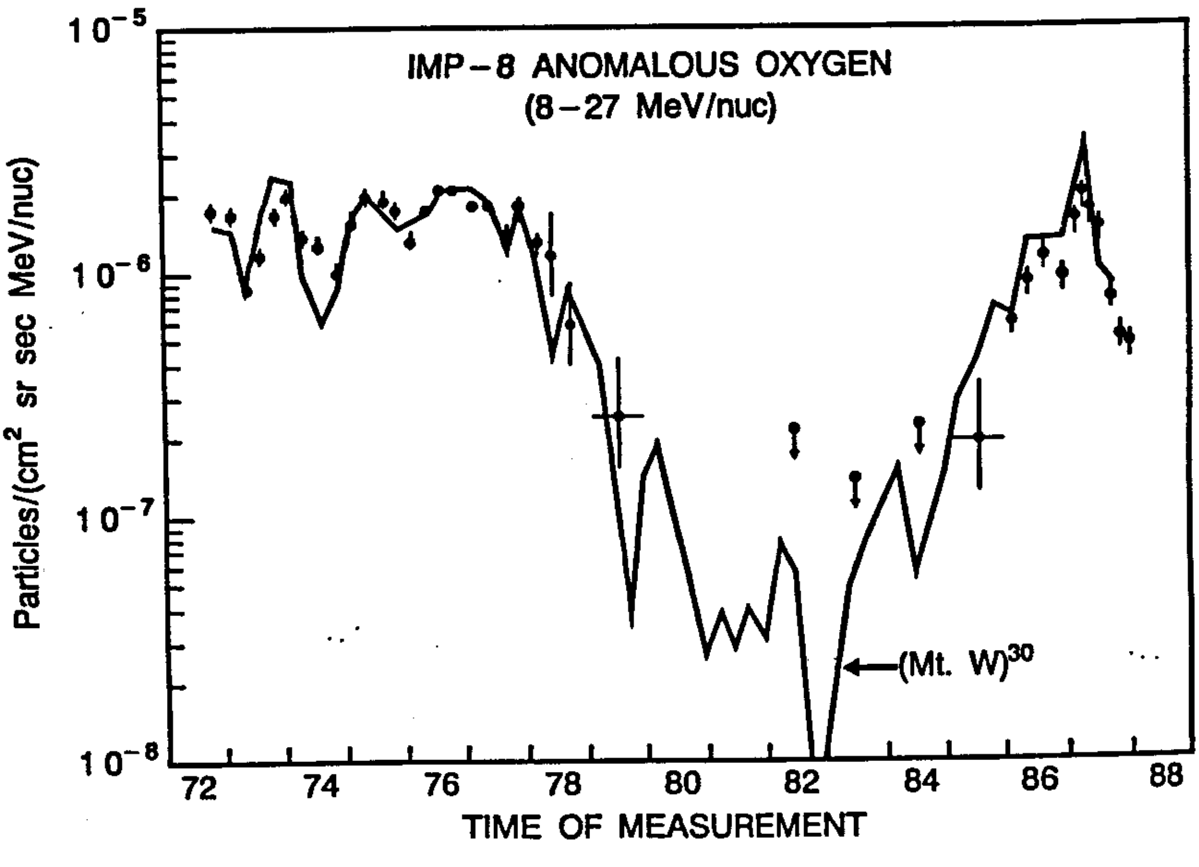



Singly-Ionized Anomalous Oxygen
Inside the Magnetosphere
Fully-Ionized Anomalous Oxygen
Inside the Magnetosphere
Particles/m^2 sec sr MeV/nuc
MeV/nuc
Sum
GCR
LEC
AC


O/C Quiet Magnetosphere
Singly Ionized
Anomalous Component
Fully Ionized
Anomalous
Component
Ratio

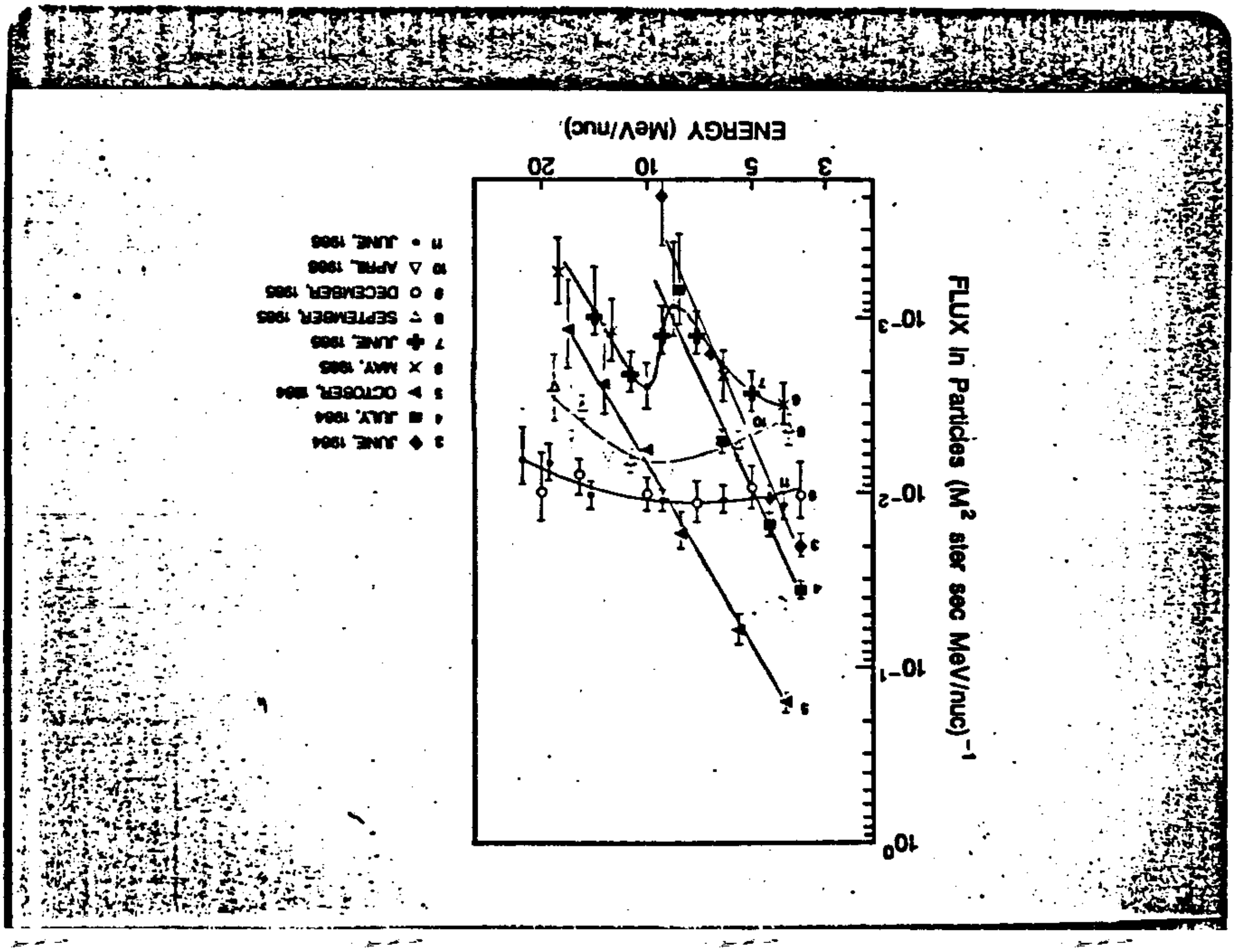
OBSERVATION OF THE AMOMALOUS OXYGEN COMPONENT (1972 - PRESENT)

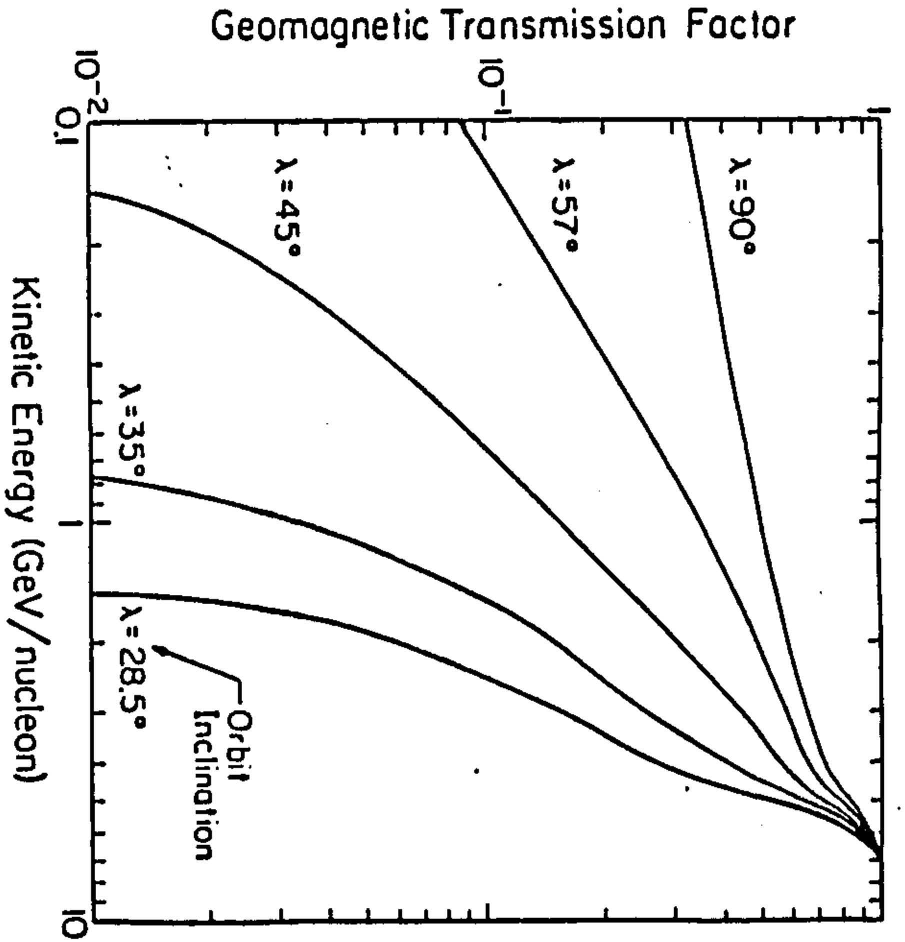
- THE ANOMALOUS OXYGEN COMPONENT PERSISTED FROM 1972 - 1979
- IN 1979 THE ANOMALOUS OXYGEN COMPONENT DISAPEARED AT 1 AU
  - BECAUSE OF INCREASING SOLAR MODULATION
- THE ANOMALOUS COMPONENT REAPPEARED AT 1 AU IN 1986, BUT WAS DISAPPEARING AGAIN BY 1988
- THIS SAME PATTERN SHOULD BE REFLECTED IN THE COSMOS DATA OF GRIGOROV *et al* OVER THE SAME TIME PERIOD
  - PROVIDED THEY ARE PREDOMINATELY OBSERVING THE ANOMALOUS COMPONENT
- FURTHERMORE, THE INTENSITY OF IONS IN THE GRIGOROV DATA SHOULD REFLECT THE CHARGE STATE OF THE IONS

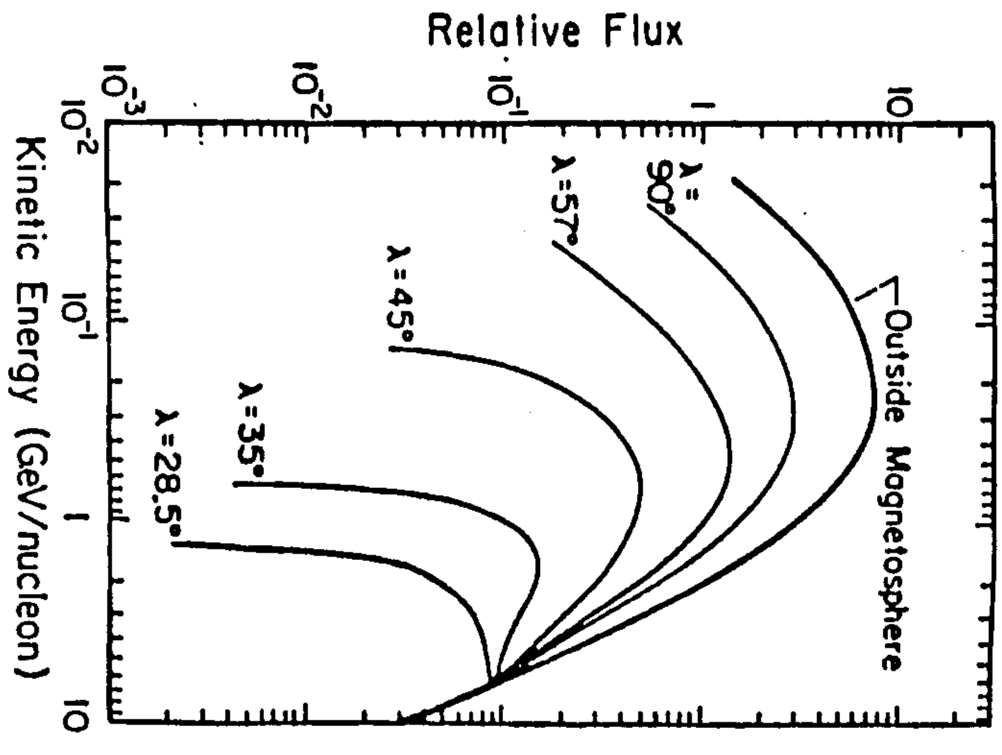


COSMOS DATA REPORTED BY GRIGOROV *et al* AT 20th ICRC/MOSCOW

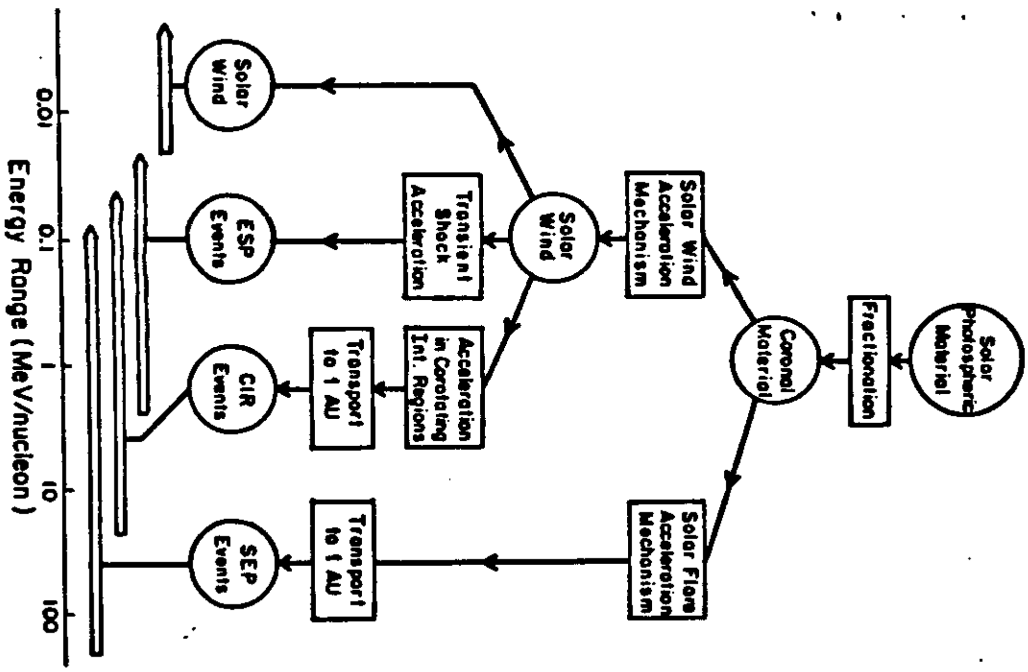
- DATA ARE FROM COSMOS-EXPOSURES OF PLASTIC TRACK DETECTORS
  - EXPOSURE TIMES OF APPROXIMATELY 14 DAYS EACH
  - DURING PERIOD JUNE 1984 TO JUNE 1986
- SPECTRA SHOW COMBINED DATA FOR ELEMENTS OF CARBON AND HEAVIER NUCLEI
- IT WAS REPORTED THAT THE FLUX IN FLIGHTS 6 THROUGH 11 WAS DOMINATED BY OXYGEN
- THE AMOMALOUS COMPONENT IS CLEARLY APPARENT IN FLIGHT 8 (SEPTEMBER 1985) AND SUBSEQUENT FLIGHTS
- BY EARLY 1986 THE AMOMALOUS COMPONENT WAS ALSO BEING OBSERVED IN THE DATA FROM US SPACECRAFT




Geomagnetic Transmission Factor
Kinetic Energy (GeV/nucleon)
λ=90°
λ=57°
λ=45°
λ=35°
λ=28.5°
Orbit Inclination


Relative Flux
Kinetic Energy (GeV/nucleon)
λ=90°
λ=57°
λ=45°
λ=35°
λ=28.5°
Outside Magnetosphere

- WE UNDERSTAND TIIAT GRIGOROV AND HIS COLLEAGUES CARRIED OUT ABOUT 10 EXPOSURES PER YEAR DURING THE PERIOD 1985 - 1988
- BY COMPARING THEIR DATA WITH COMTEMPORANEOUS DATA FROM US-SPACECRAFT OPERATING OUTSIDE THE MAGNETOSPHERE
  - IT SHOULD BE POSSIBLE TO DETERMINE THE IONIC CHARGE STATE OF THE ANOMALOUS COMPONENT
  - THIS WOULD BE A DECISIVE TEST FOR ITS THEORETICAL ORIGIN FROM LOCAL-INTERSTELLAR NEUTRAL ATOMS
- THE COMPARISON WOULD BE INVOLVE CALCULATIONS OF ORBIT-AVERAGED FLUXES FOR SINGLY-IONIZED AND FULLY-IONIZED ATOMS IN GRIGOROV'S DETECTORS
  - BASED ON EXTRAPOLATION OF THE US-SPACECRAFT-MEASURED FLUXES USING TRANSMISSION FUNCTIONS DETERMINED FOR THE SPECIFIC COSMOS ORBITS

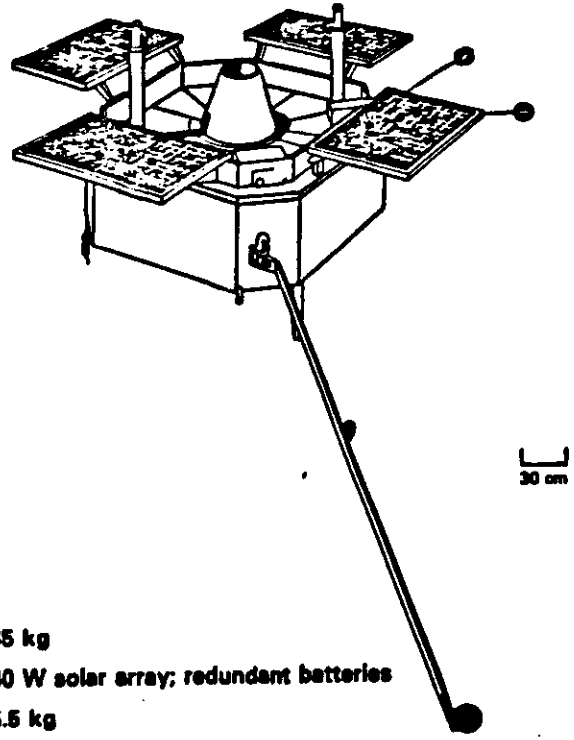


ACE Spacecraft Summary

(Basis: AMPTE/Charge Composition Explorer)

Launch Weight (includes 100 kg of experiments)	300 kg
Power	140 W
Telemetry (tape recorder, daily readout)	3-10 kb/s
Attitude control (spin axis points at sun)	spinning
Orbit (extra-magnetospheric)	Lagrangian point (240 R_E) or Geocentric (40-50 R_E)

AMPTE CHARGE COMPOSITION EXPLORER SPACECRAFT



MASS:	245 kg
POWER:	140 W solar array; redundant batteries
EXPERIMENT PAYLOAD:	36.5 kg
ATTITUDE CONTROL:	Spin stabilized; redundant solar aspect sensors; Freon thrusters; magnetic X, Y, and Z torquing; triaxial fluxgate magnetometer on 2.4 m boom
DATA HANDLING SYSTEMS:	Redundant microprocessor-based data and command systems; 2 × 10^8 bit tape recorder; redundant 2.5 W S-band NASA standard transponders; data rate — tape playback 105.6 kbps, real time 3300
PROPULSION:	49 kg Star 13A solid rocket
OPERATIONS:	JPL Multispacecraft Control Center
SCIENCE:	AMPTE Science Data Center at APL/JHU

ACE Instrumentation

Advanced Spectrometers

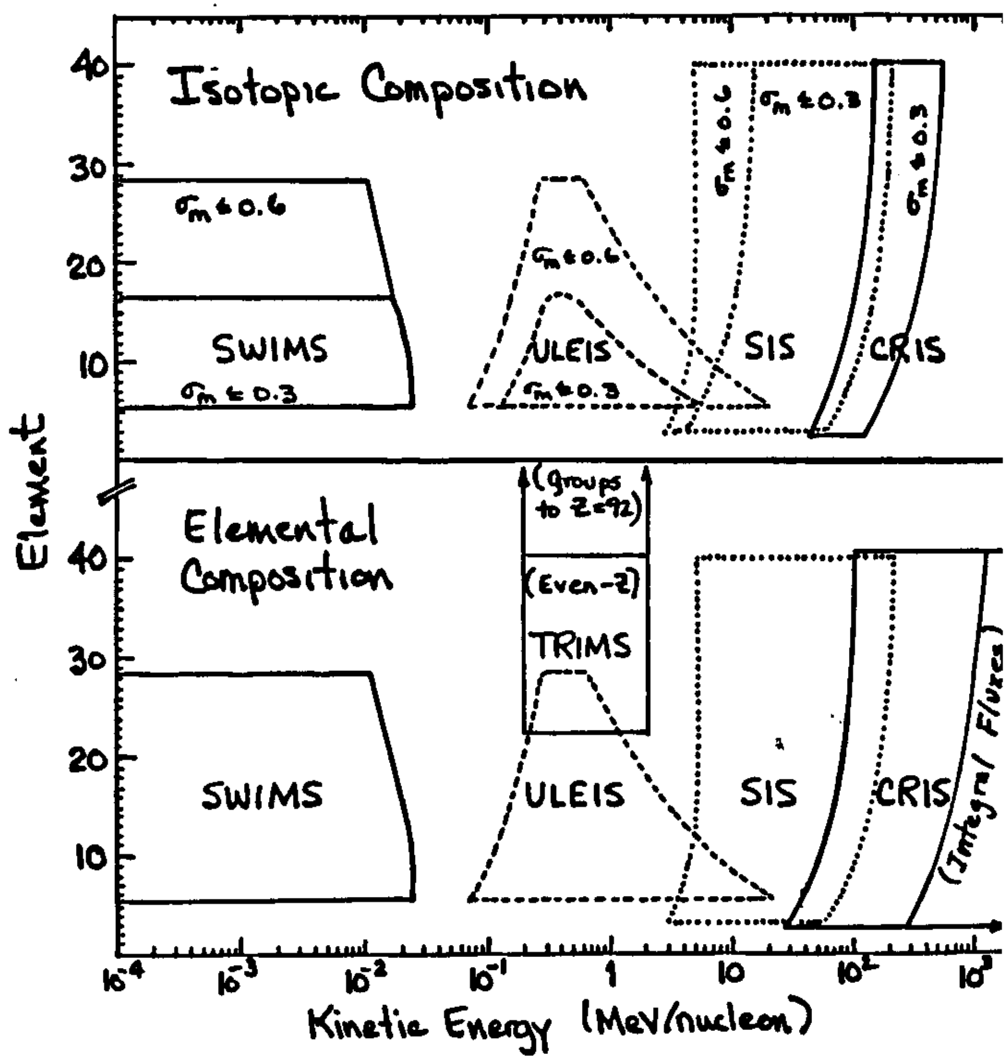
CRIS - Cosmic Ray Isotope Spectrometer	$\Delta E \times E$
SIS - Solar Isotope Spectrometer	$\Delta E \times E$
TRIMS - Trans-Iron Mass Spectrometer	TOF x E
ULEIS - Ultra-Low-Energy Isotope Spectrometer	TOF x E
SWIMS - Solar Wind Ion Mass Spectrometer	TOF x E x E/Q

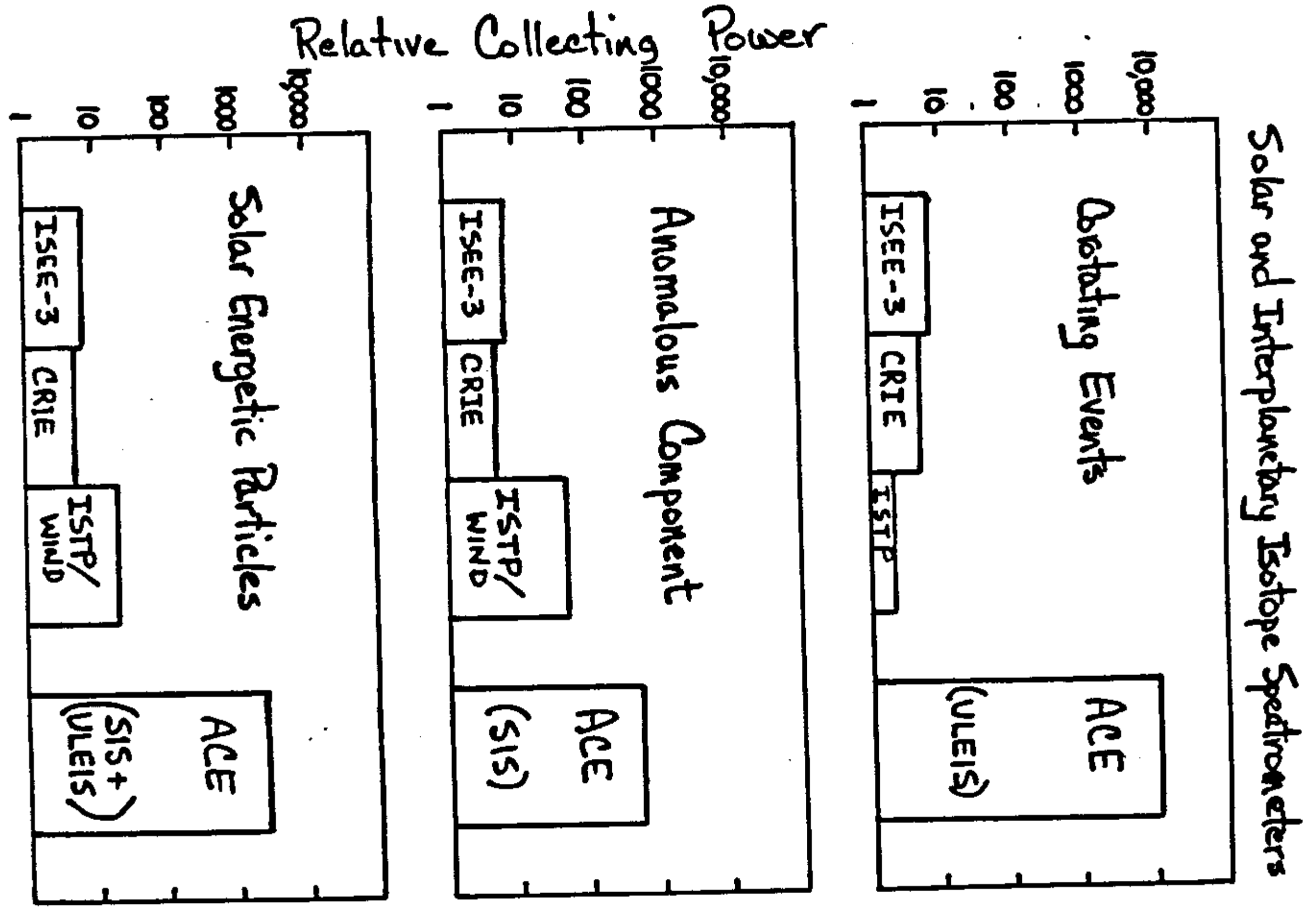
Baseline Monitors

SWEPAM - Solar Wind Electrons, H, He

EPAM - Energetic H, He

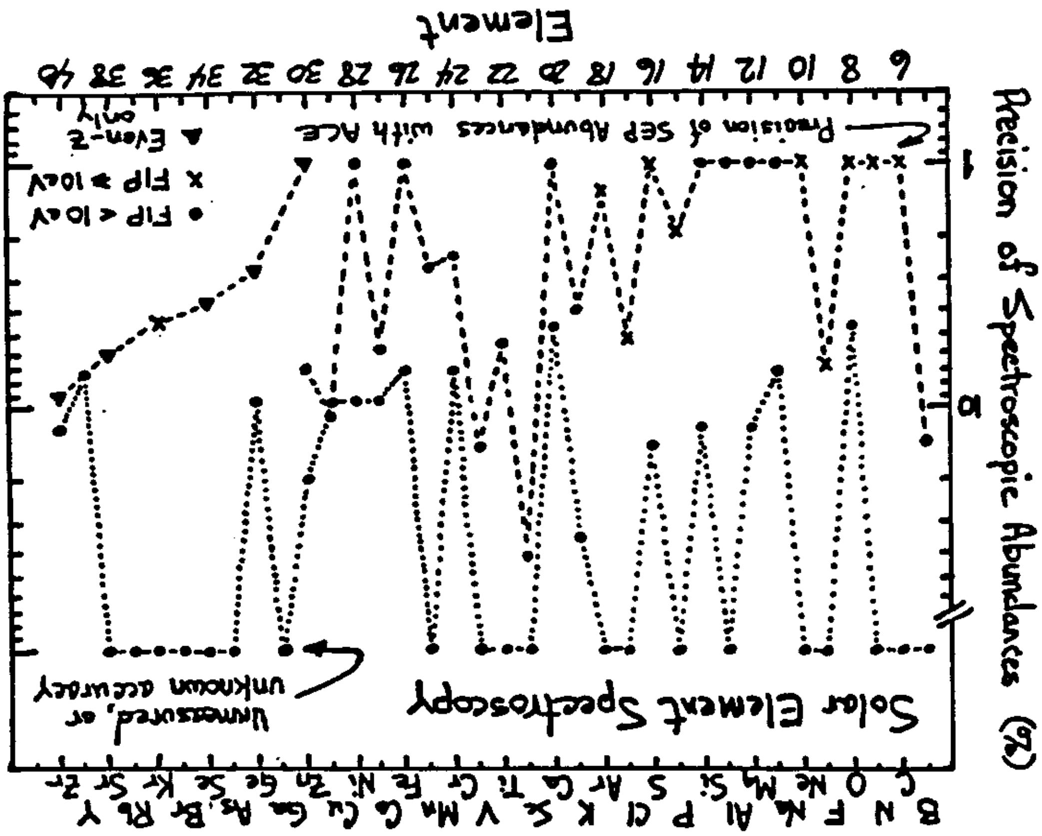
MAG - Magnetic Field





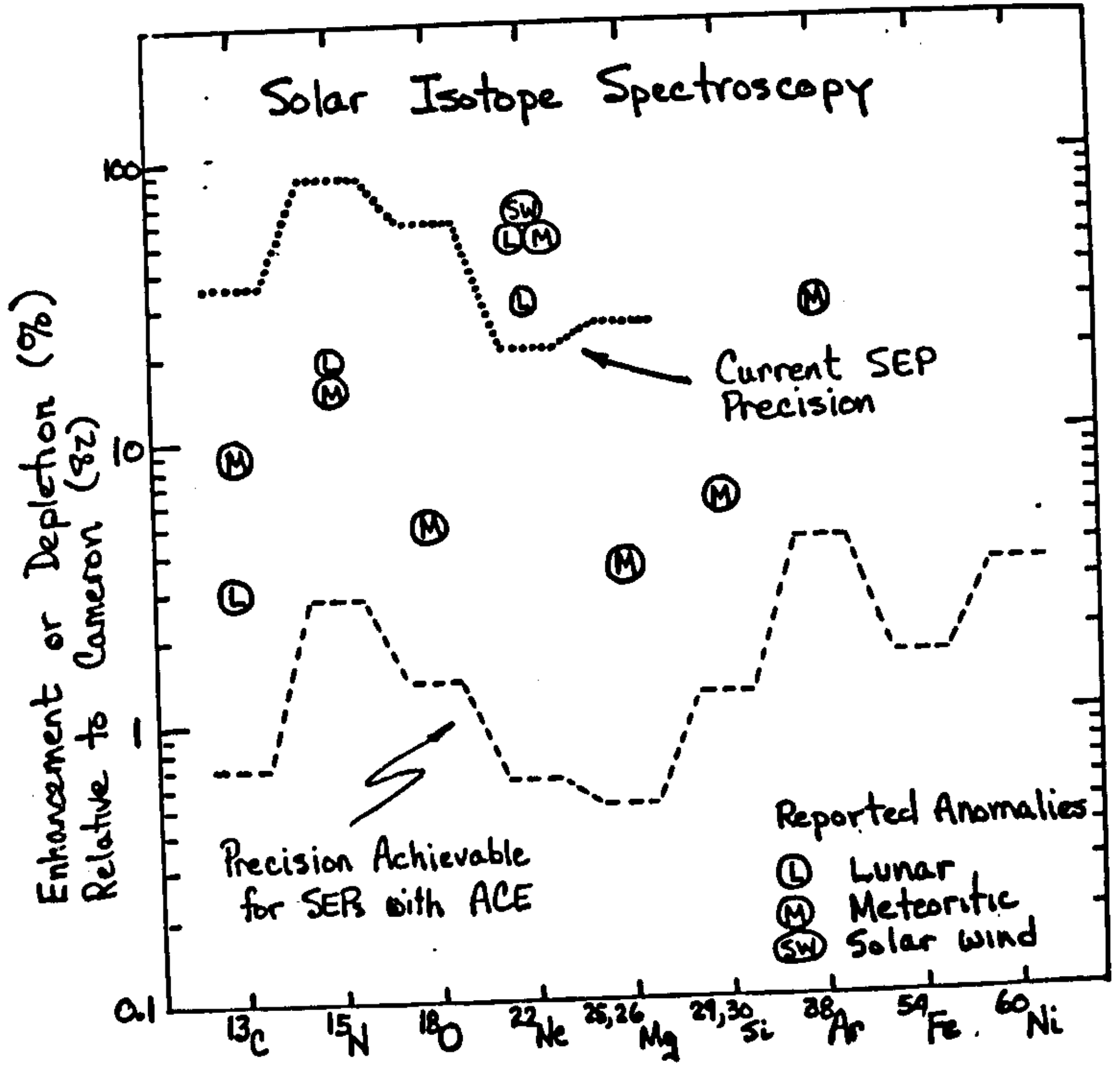
SOLAR ELEMENT SPECTROSCOPY

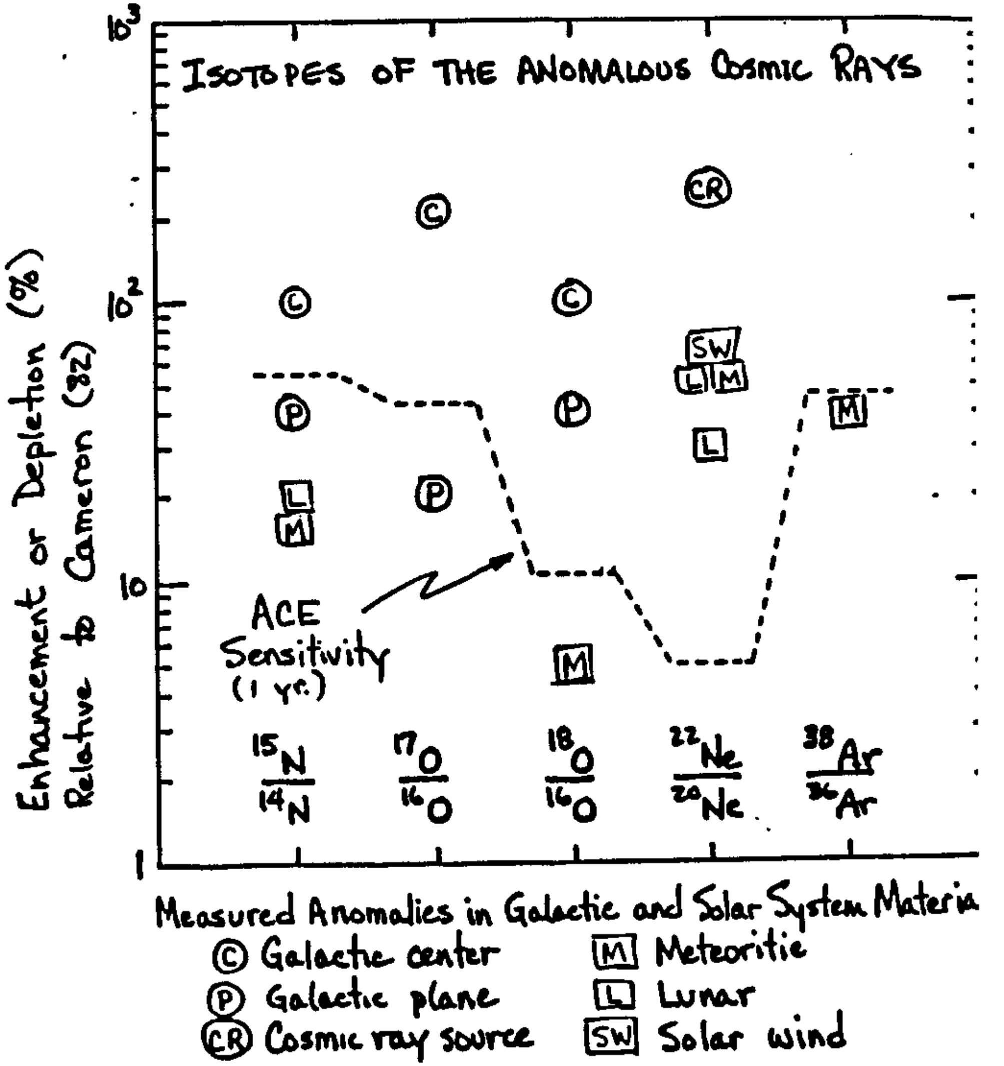
- IN LARGE SOLAR FLARES THE ELEMENTAL COMPOSITON VARIES FROM FLARE TO FLARE
  - FRACTIONATION OF DIFFERENT ELEMENTS IS FUNCTION OF RIGIDITY OF NUCLEI
  - PROBABLY REFLECTS RIGIDIGY-DEPENDENT ACCELERATION AND PROPAGATION
- DERIVE UNFRACTIONATED CORONAL ABUNDANCES USING ION CHARGE STATES
  - GET AGREEMENT WITH SPECTROSCOPICALLY-DETERMINED CORONAL ABUNDANCES AND SOLAR WIND MEASUREMENTS
- THE SEP-DERIVED CORONAL AND PHOTOSPEHRIC ABUNDANCES DIFFER FROM THE ASSUMED SOLAR ABUNDANCES FOR SEVERAL KEY ELEMENTS SUCH AS C AND Fe
  - HOWEVER, MOST ACCURATELY KNOWN ABUNDANCES ARE UNCERTAIN TO ABOUT 10%
- ACE WILL IMPROVE THE ABUNDANCE DETERMINATIONS BY FACTOR OF 10 - 100
- ACE WILL EXTEND THE MEASUREMENTS UP TO Zr (Z = 40)
  -- WITH ACCURACY COMPARABLE TO METEORITIC ABUNDANCES



ISOTOPIC AND ELEMENTAL SOLAR ABUNDANCES

- SUN CONTAINS >99% OF SOLAR SYSTEM MATERIAL, BUT
  - WE HAVE ONLY LIMITED DIRECT KNOWLEDGE OF ITS ELEMENTAL COMPOSITON
  - WE HAVE NO DIRECT KNOWLEDGE OF ITS ISOTOPIC COMPOSITION
  - SPECTROSCOPIC MEASUREMENTS OF ONLY FEW ISOTOPES (VERY DIFFICULT)
  - ISOTOPES IN CAMERON'S TABLE OF "SOLAR SYSTEM" ABUNDANCES ARE BASED ON TERRESTRIAL MATERIAL
  - METEORITES ARE THE STANDARD SOURCE FOR ELEMENTAL ABUNDANCES
- ISOTOPIC ANOMALIES DISCOVERED IN > 20 DIFFERENT ELEMENTS
- ACE OFFERS THE BASIS FOR THE FIRST EXTENSIVE COMPILATION OF ISOTOPIC AND ELEMENTAL ABUNDANCES USING DIRECT SAMPLING OF SOLAR MATERIAL


Solar Isotope Spectroscopy
Enhancement or Depletion (%)
Relative to Cameron (82)
100
10
1
0.1
Current SEP Precision
Precision Achievable for SEP with ACE
Reported Anomalies
L Lunar
M Meteoritic
SW Solar wind
13C
15N
18O
22Ne
25,26Mg
29,30Si
38Ar
54Fe
60Ni

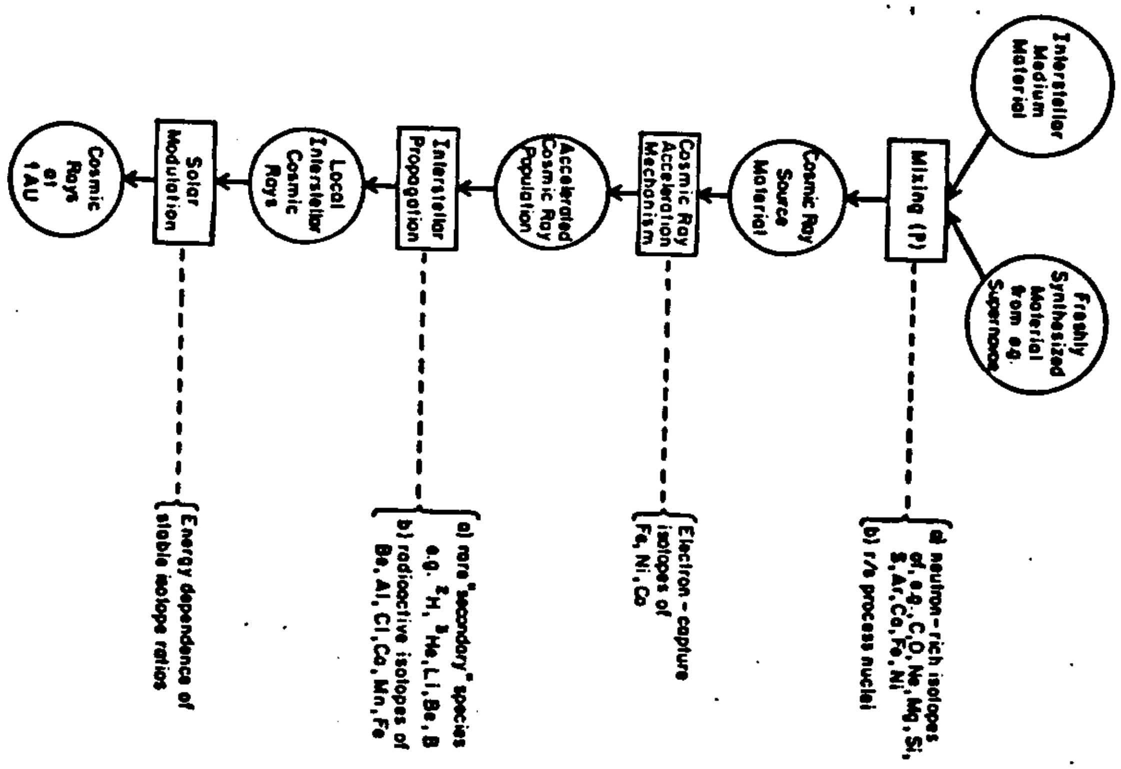

ISOTOPES OF THE ANOMALOUS COSMIC RAYS
Enhancement or Depletion (%)
Relative to Cameron (82)
10^3
10^2
10
1
ACE Sensitivity (1 yr.)
15N/14N
17O/16O
18O/16O
22Ne/20Ne
38Ar/36Ar
Measured Anomalies in Galactic and Solar System Materia
C Galactic center
P Galactic plane
CR Cosmic ray source
M Meteoritic
L Lunar
SW Solar wind

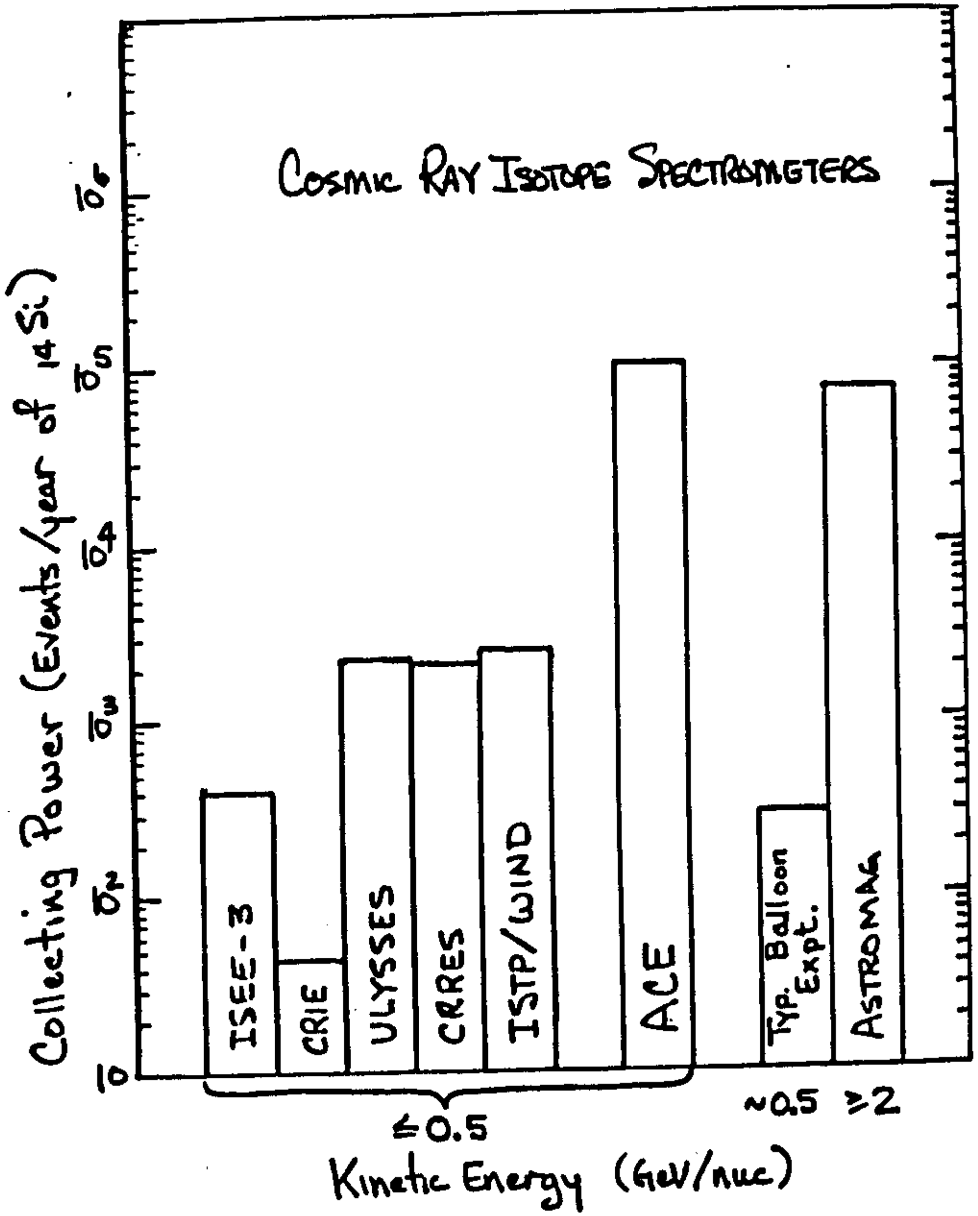
ISOTOPIC AND ELEMENTAL SOLAR ABUNDANCES

CONT'D

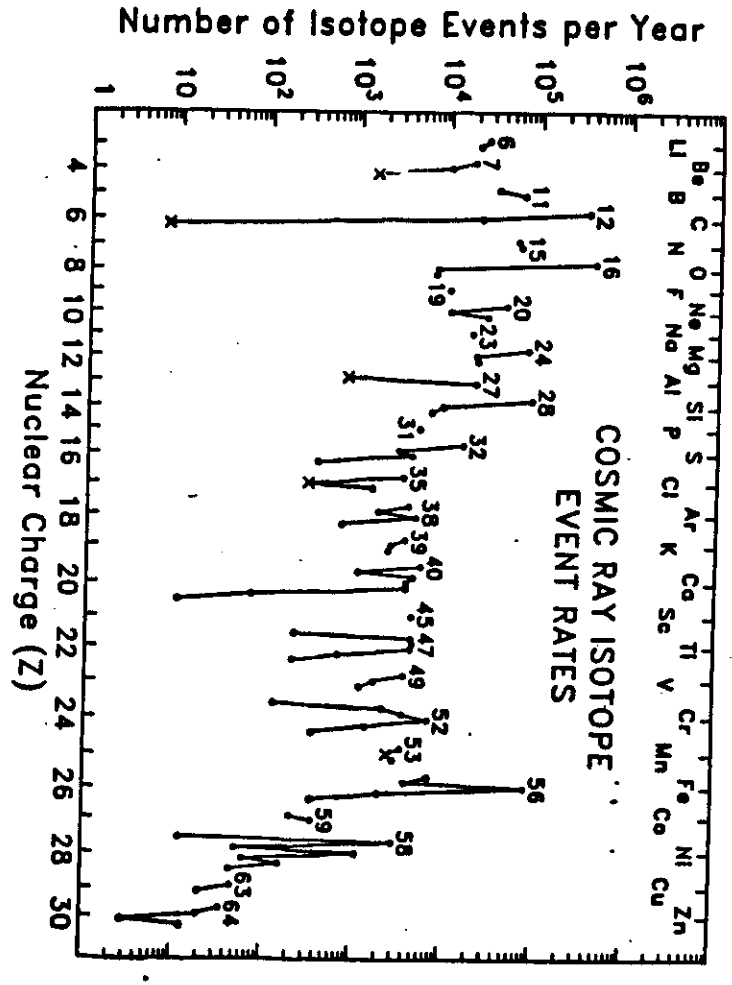
- NOTE THAT CURRENT TABULATIONS BASED ON METEORITES AND LUNAR SAMPLES (E.G., CAMERON AND ANDERS & EBIHARA) ARE ESSENTIAL BENCH MARKS FOR:

- PLANETARY GEOLOGY STUDIES
- OPTICAL AND X-RAY OBSERVATIONS OF THE SUN
- NUCLEOSYNTHESIS AND STELLAR EVOLUTION THEORY
- ESSENTIALLY ALL STUDIES OF CHARGED PARTICLE COMPOSITONS IN SPACE





Cosmic Ray Isotope Spectrometers
Collecting Power (Events/year of 14 Si)
ISEE-3
CRIE
ULYSSES
CRRES
ISTP/WIND
ACE
Typ. Balloon Expt.
ASTROMAG
≤0.5
~0.5
≥2
Kinetic Energy (GeV/nuc)



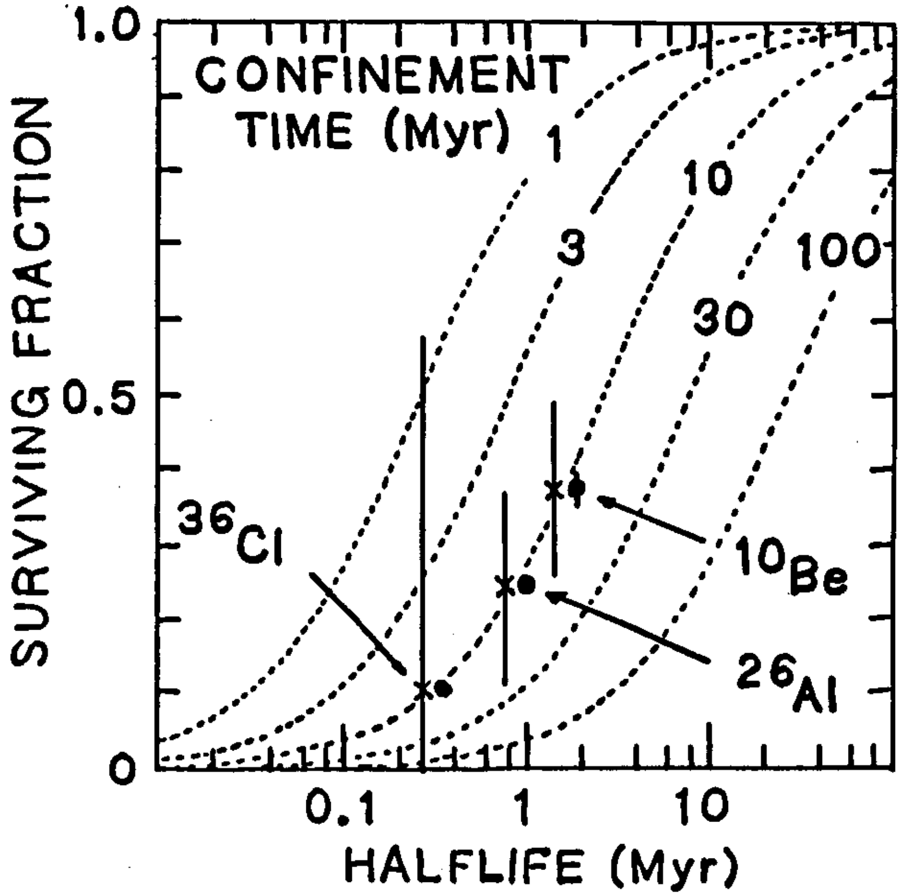
Number of Isotope Events per Year
COSMIC RAY ISOTOPE EVENT RATES
Nuclear Charge (Z)

Classification of the Cosmic Ray Isotopes

Element	Primary	Secondary	Mixed
Hydrogen	^{1}H	^{2}H	
Helium	^{4}He	^{3}He	
Lithium		^{6}Li, ^{7}Li	
Beryllium		^{7}Be*, ^{9}Be, ^{10}Be*	
Boron		^{10}B, ^{11}B	
Carbon	^{12}C	^{14}C*	^{13}C
Nitrogen		^{15}N	^{14}N
Oxygen	^{16}O	^{17}O	^{18}O
Fluorine		^{19}F	
Neon	^{20,22}Ne	^{21}Ne	
Sodium			^{23}Na
Magnesium	^{24}Mg, ^{25}Mg, ^{26}Mg		
Aluminum		^{26}Al*	^{27}Al
Silicon	^{28}Si, ^{29}Si, ^{30}Si		
Phosphorous		^{31}P	
Sulphur	^{32}S, ^{34}S	^{33}S	^{36}S
Chlorine		^{36}Cl*	^{35}Cl, ^{37}Cl
Argon	^{36}Ar, ^{38}Ar	^{37}Ar*, ^{40}Ar	
Potassium		^{40}K*	^{39}K, ^{41}K
Calcium	^{40}Ca, ^{44}Ca	^{41}Ca*, ^{43}Ca, ^{46}Ca	^{42}Ca, ^{48}Ca
Scandium		^{45}Sc	
Titanium		^{44}Ti*, ^{46}Ti, ^{47}Ti, ^{49}Ti, ^{50}Ti	^{48}Ti
Vanadium		^{49}V*, ^{50}V*, ^{51}V	
Chromium		^{50}Cr, ^{51}Cr*, ^{53}Cr, ^{54}Cr	^{52}Cr
Manganese		^{53}Mn*, ^{54}Mn*	^{55}Mn
Iron	^{56}Fe, ^{57}Fe, ^{58}Fe	^{55}Fe*, ^{60}Fe*	^{54}Fe
Cobalt	^{59}Co	^{57}Co*	
Nickel	^{58}Ni, ^{60}Ni, ^{62}Ni, ^{64}Ni	^{56}Ni*, ^{59}Ni*	^{61}Ni
Copper			^{63}Cu, ^{65}Cu
Zinc	^{64}Zn, ^{66}Zn, ^{68}Zn	^{67}Zn	^{70}Zn

*Long-lived Radioactive Isotope

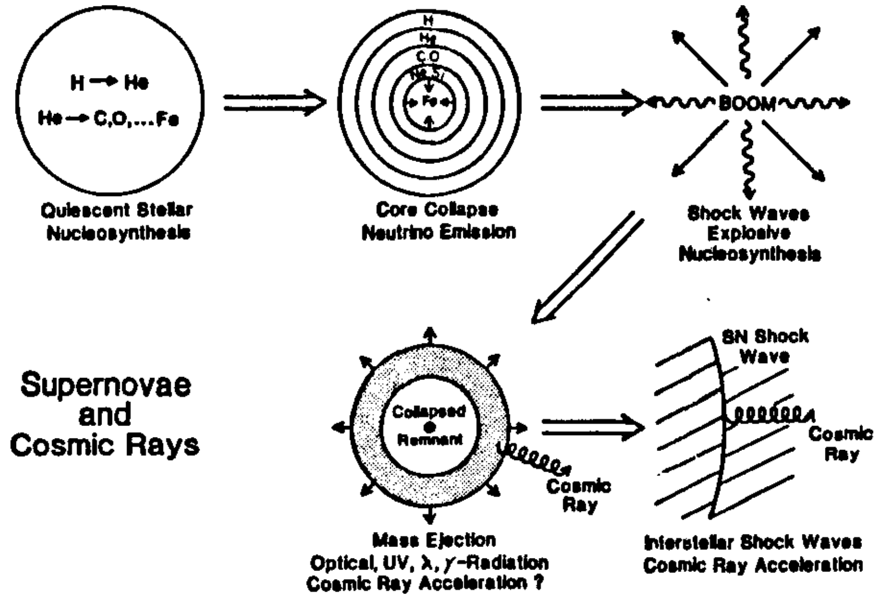
RADIOACTIVE "CLOCK" ISOTOPE

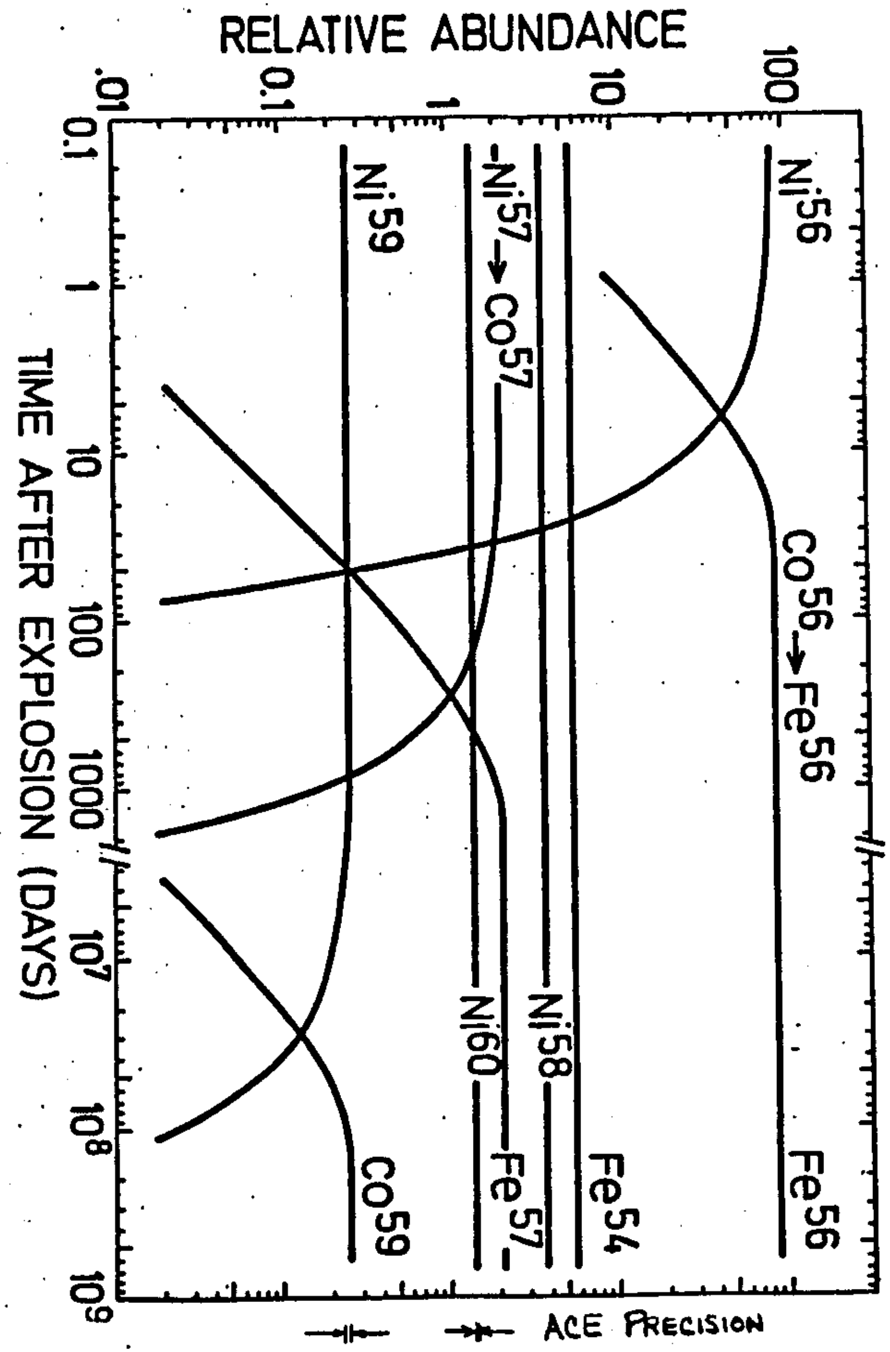


The Time Delay Between Nucleosynthesis and Cosmic Ray Acceleration

Supernova explosions in the galaxy are believed to provide the energy responsible for accelerating cosmic ray nuclei to high energy. It is not known, however, whether this acceleration occurs immediately via shock acceleration during the birth and infancy of the supernova, or much later on, as supernova shock waves from older supernovae make multiple encounters with material in the interstellar medium. In one case cosmic rays would consist of freshly synthesized material ejected from the supernova, while in the second cosmic rays would include contributions from element synthesis integrated over the age of the galaxy.

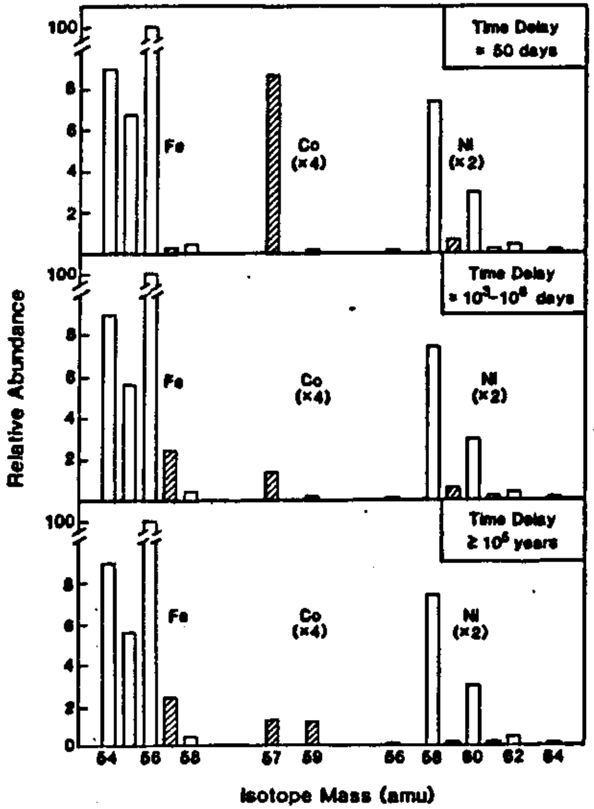
This fundamental question could be addressed by a cosmic ray composition Explorer such as ACE by measuring radio-active isotopes produced during the supernova explosion that decay only by electron capture, including ^{56}Ni, ^{57}Co, and ^{59}Ni, which have radioactive half-lives ranging from a few days (^{56}Ni) to $\sim 10^5$ years (^{59}Ni). Once accelerated and stripped of their electrons these nuclei can no longer decay, and their abundances therefore preserve a record of the time-delay between nucleosynthesis and acceleration to high energy.





For example, if this time delay is more than a few days, as is expected on theoretical grounds, most of the ^{56}Ni will have decayed to ^{56}Co, which then decays to ^{56}Fe, producing the 0.847 MeV γ-rays that are currently being searched for from SN 1987a in the LMC. If the time delay is much greater than a thousand days, most of the ^{57}Ni produced during the explosion will have decayed to ^{57}Fe. Finally, if the time delay is much more than 100,000 years, the ^{59}Ni will have decayed to ^{59}Co.

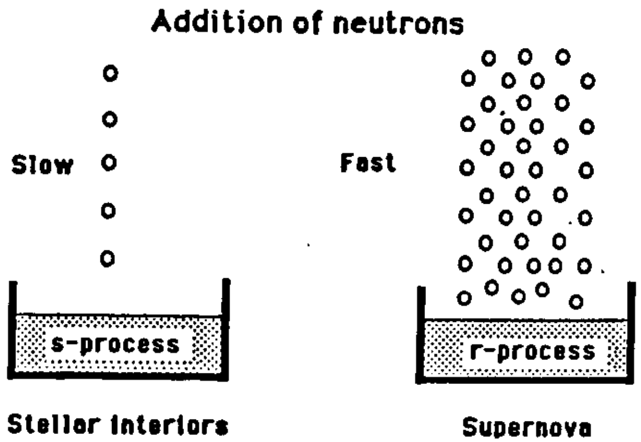
Thus, a measurement of the isotopic composition of cobalt may provide critical information about supernovae and their role in accelerating cosmic rays. Further evidence of explosive nucleosynthesis in supernova can be obtained from observations of the abundances of a variety of other isotopes in cosmic rays, including neutron-rich isotopes of the elements Ne, Mg, Si, Fe, and Ni.



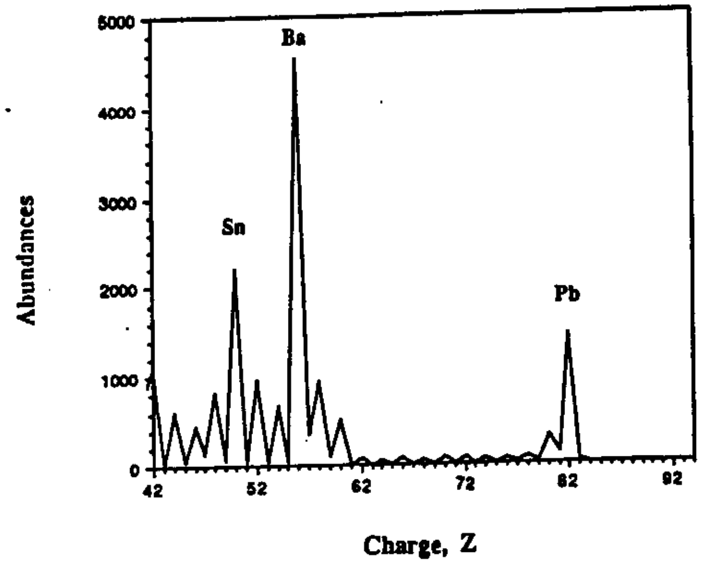
Expected yields of Fe, Co, and Ni isotopes as a function of the time delay between nucleosynthesis and cosmic ray acceleration. The abundances of those nuclei (e.g., ^{57}Co and ^{59}Co) that are especially sensitive to this time delay are shaded.

Nucleosynthesis and the UH-Nuclei

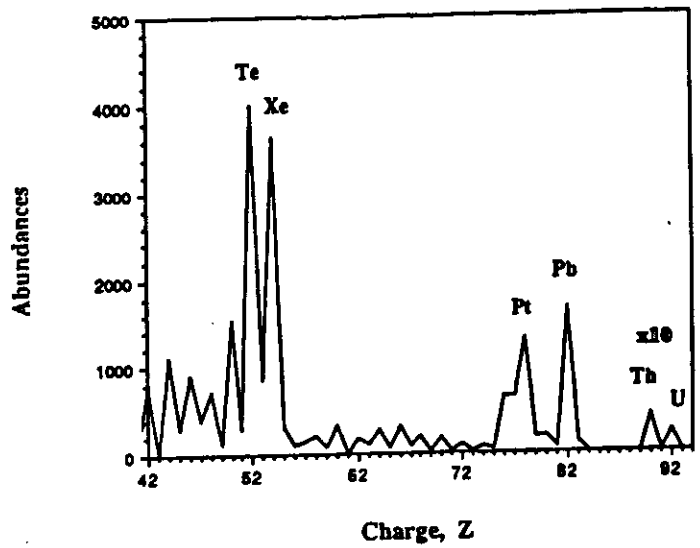
The ultraheavy (UH) elements, which comprise the upper 2/3 of the periodic table, are synthesized by the addition of neutrons to seed nuclei of iron and nickel; either slowly in the later stages of stellar evolution ("s-process"), or rapidly in the explosive stages of supernova events ("r-process"). Solar material is found to consist of a mixture of elements produced by these two processes, while the cosmic rays appear to contain a somewhat different mix. A more precise determination of these differences than is now possible would define the nature of the material that is accelerated to cosmic ray energies and hence allow a description of the source.

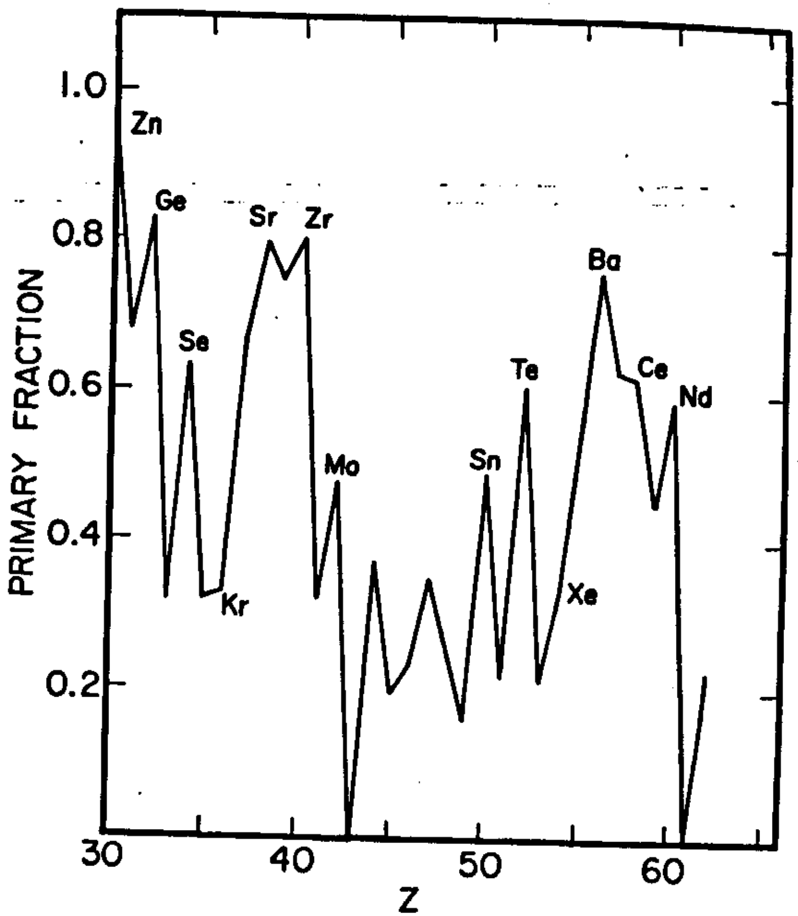


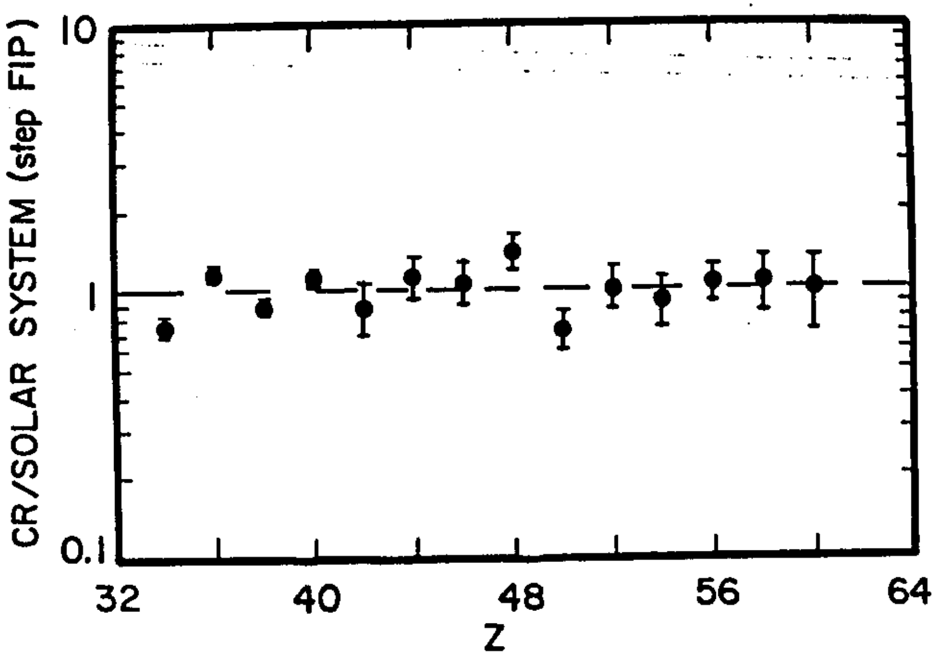
Abundances from s-Process

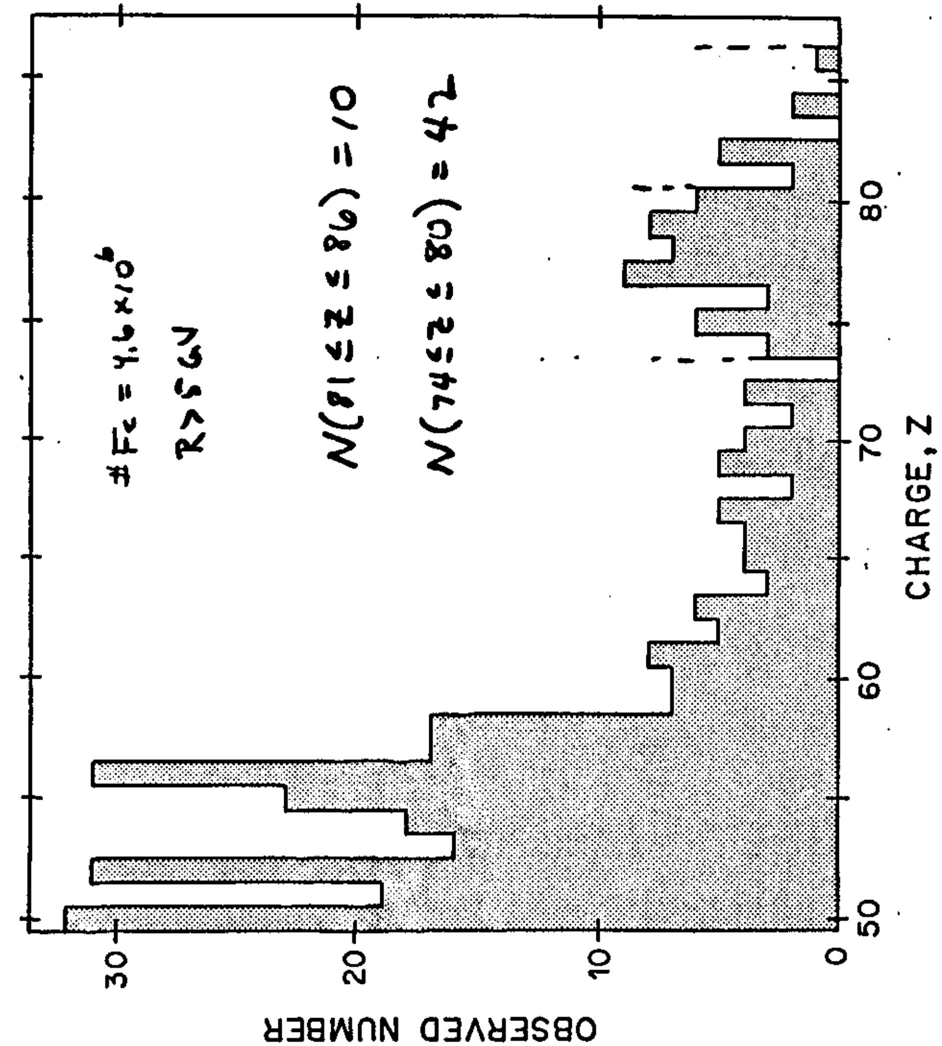


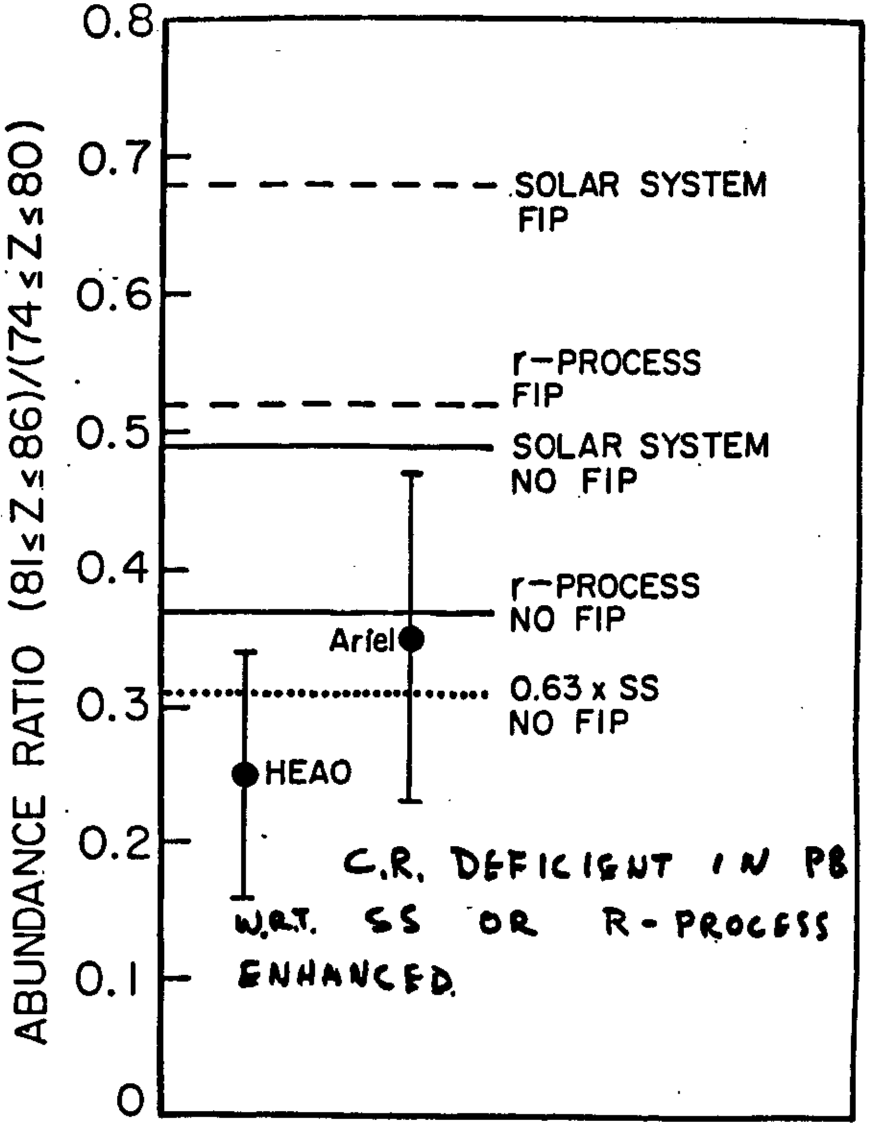
Abundances from r-Process

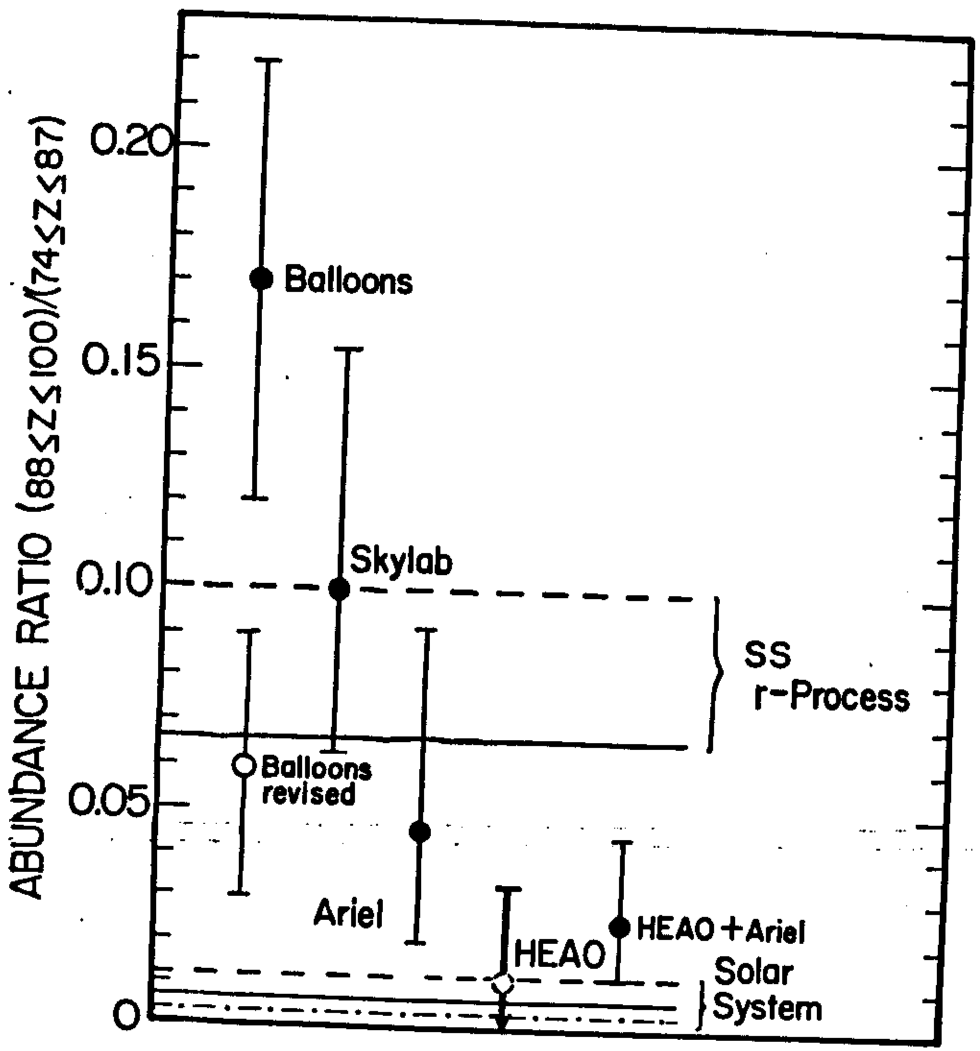




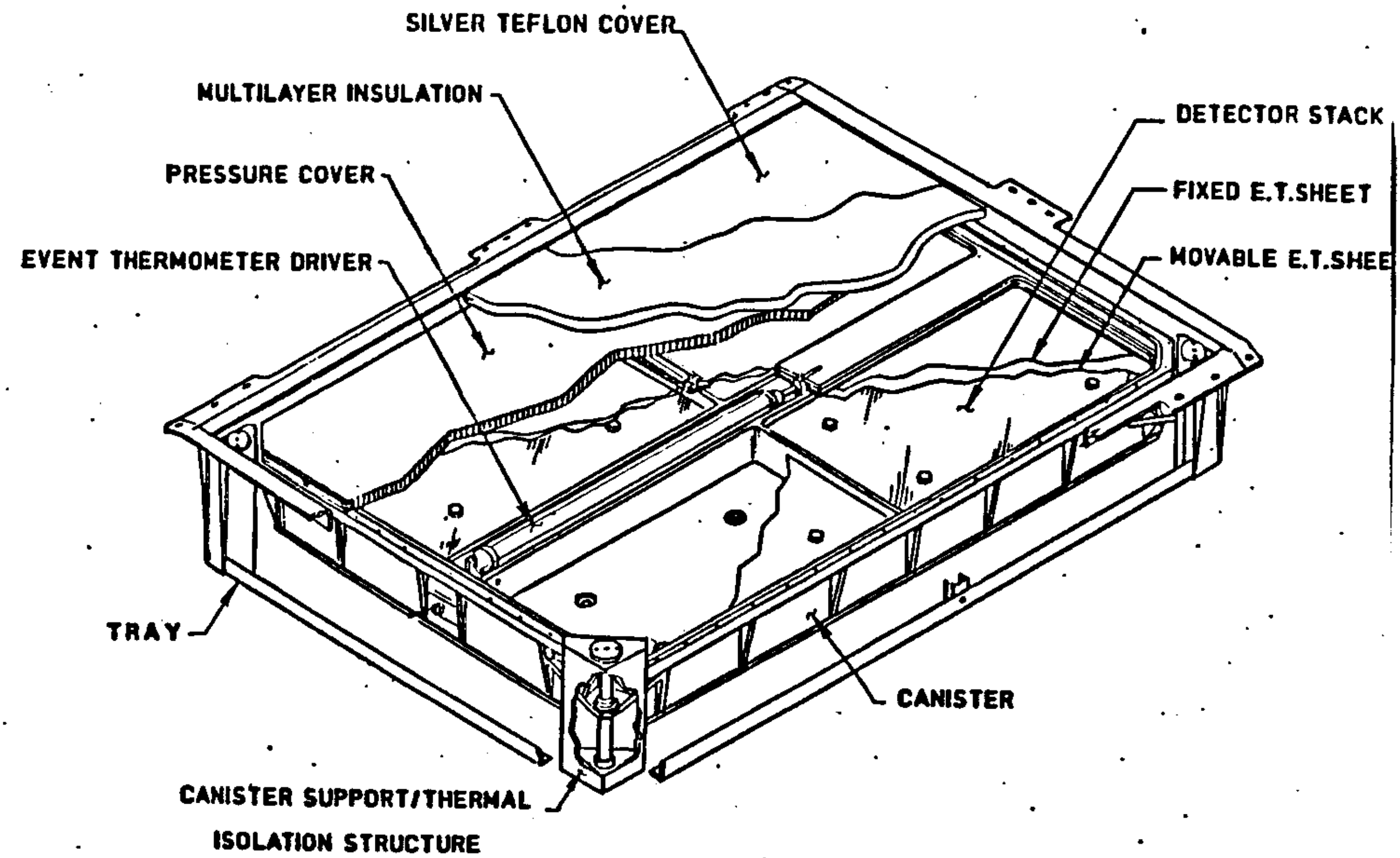

CR/SOLAR SYSTEM (step FIP)
10
1
0.1
32
40
48
56
64
Z

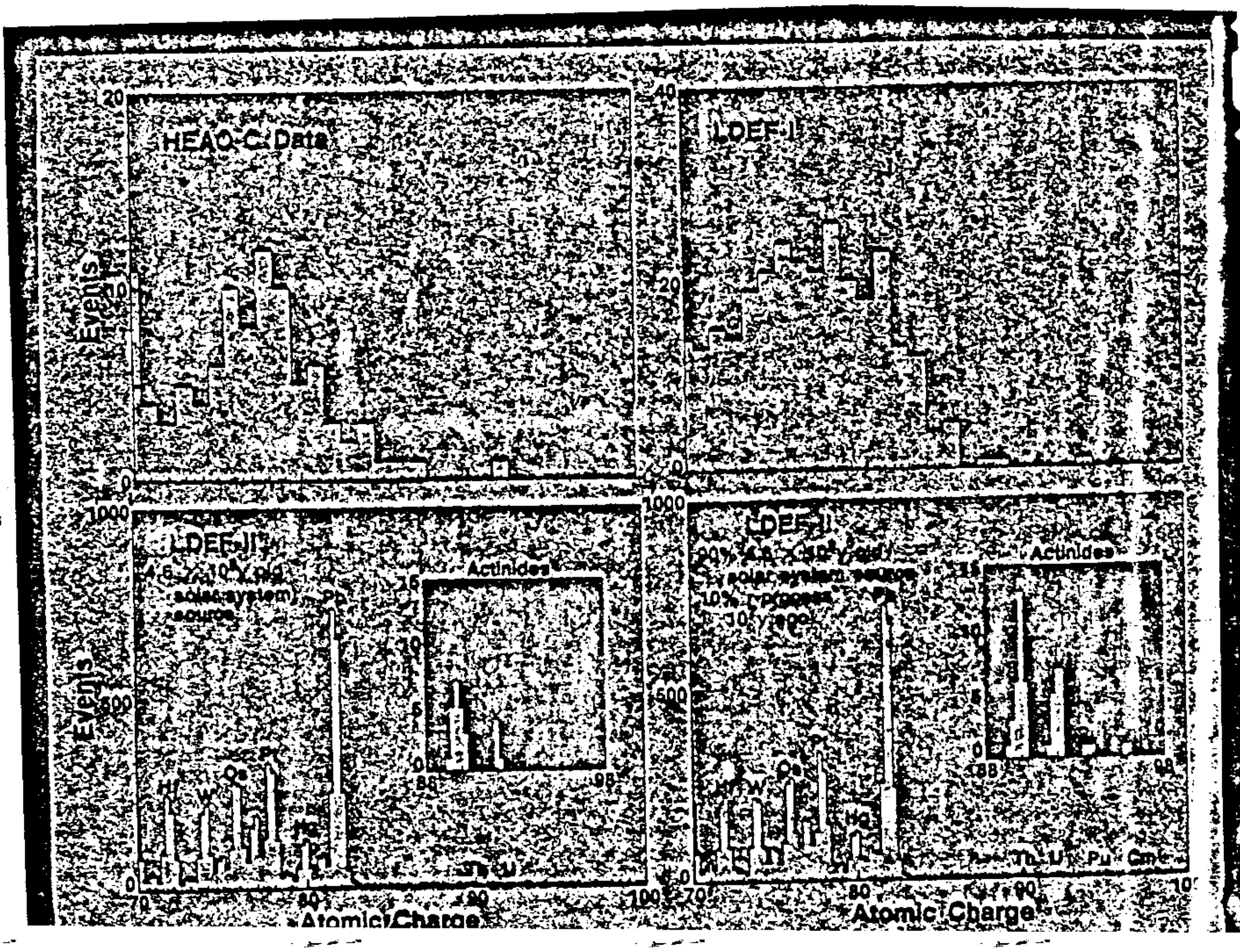

OBSERVED NUMBER
30
20
10
0
CHARGE, Z
50
60
70
80
N(81 ≤ Z ≤ 86) = 10
N(74 ≤ Z ≤ 80) = 42
R > 5 GV


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ABUNDANCE RATIO (81≤Z≤86)/(74≤Z≤80)
SOLAR SYSTEM FIP
r−PROCESS FIP
SOLAR SYSTEM NO FIP
r−PROCESS NO FIP
0.63 x SS NO FIP
Ariel
HEAO
C.R. DEFICIENT IN PB W.R.T. SS OR R-PROCESS ENHANCED.


0.20
0.15
0.10
0.05
0
ABUNDANCE RATIO (88≤Z≤100)/(74≤Z≤87)
Balloons
Skylab
SS r−Process
Balloons revised
Ariel
HEAO
HEAO + Ariel
Solar System

LDEF—1B HEAVY NUCLEI COLLECTOR EXPERIMENT





Examples of Possible Actinide Event Rates for LDEF-II HNC

	Th	U	Np	Pu	Cm
Solar system abundances at birth	30	10	0	0	0
Solar system abundances now (SS)	21	5	0	0	0
80% SS + 20% 10^6 y-old r-process material	23	17	6	5	6
80% SS + 20% 10^7 y-old r-process material	23	17	0.4	5.8	3.6
80% SS + 20% 10^8 y-old r-process material	27	17	0	2	0
100% 10^7 y-old r-process material	7	83	2	29	18

SUMMARY

1. GENERAL GOOD AGREEMENT WITH SS + STEP FIP.
2. GE + PB ARE EXCEPTIONS
   - BOTH VOLATILE
   - BOTH SS ABUNDANCES LOWER IN RECENT PHOTOSPHERE STUDIES
3. THE CR SOURCE IS NOT DOMINATED BY R-PROCESS.
   - Sr/Rb ⇒ not R PROCESS
   - Sn + Ba Abundant
   - Th + U NOT MUCH ENHANCED (BUT Pt/Pb + ACTINIDE/Pt+Pb CONSISTENT WITH SOME R-PROCESS ENHANCEMENT)
4. PRESENT SITUATION
   - CR MEASUREMENT PRECISION IS BETTER THAN CURRENT KNOWLEDGE OF CORRECT STANDARD.