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COSMIC RAY ELEMENTAL ABUNDANCES FOR $26 \leq Z \leq 42$ MEASURED ON HEAO-3

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1. Introduction

Measurements from the Heavy Nuclei Experiment (Binns et al. 1981a) aboard the HEAO-3 satellite have been used to extract definite abundance values for the even charge nuclei and upper limit values for the less abundant odd charge nuclei. Individual peaks in the charge spectrum for even charge nuclei over this charge region are observed and the cosmic ray abundances obtained from this charge spectrum are compared with abundances characteristic of the solar system and with a solar system r process.

This paper presents an analysis of 454 days of data, about half of which has been reported on previously (Binns et al. 1981b). In the present analysis we have used an improved charge estimation algorithm, obtained a more precise normalization of $32 \leq Z \leq 42$ abundances relative to iron, have used more accurate detector response maps than previously, and have recognized and rejected a small class of events which had been previously misidentified.

There are two subsets of data used in this analysis. The "low energy" data (LE) are nuclei with kinetic energy $450 < E < 1100$ MeV/amu at the top of the detector for Fe with charge assignment obtained from the ionization and Cherenkov measurements, taking into account the change in signals due to the LE nuclei slowing down as they traverse the detector. The second subset of data, designated "high rigidity" (HR), refers to nuclei that were recorded at a geomagnetic cutoff greater than 8 GV. At such high rigidities the Cherenkov response is nearly independent of energy and we assign a value of Z based on the Cherenkov signal alone, using the iron as normalization and again assuming that C varies as Z^2.

2. Results

Figures 1a and 1b show data for the "HR" and the "LE" events respectively for $31 \leq Z \leq 45$. To obtain a normalization of these data to the much more abundant iron nuclei we have selected a subset of data consisting of 1/40 of all events in this data set selected at random throughout the time interval. A histogram of the nuclei with $24 \leq Z \leq 28$ for the combined LE and HR data is shown in Fig. 2a along with the corresponding data for $Z \geq 31$ (Fig. 2b). The iron abundances for the LE, HR, and combined data were obtained by performing a least squares fit in which the charge distribution was assumed to be gaussian and centered at integral charge values. The abundances of $31 \leq Z \leq 42$ for even Z were obtained similarly except that sigma was allowed to vary linearly with charge according to $\sigma = m(Z-26) + \sigma_{Fe}$ with σ_{Fe} fixed at the best fit value for iron and m varying. The upper limit abundances for the odd Z nuclei were obtained by fitting the data with a constant sigma equal to the sigma of the iron peak (σ_{Fe}=0.34cu), and adding the 1 sigma fitting error to these abundances. Thus these limits are conservative 83% confidence level upper limits (Table 1). The values in brackets are best fit values.

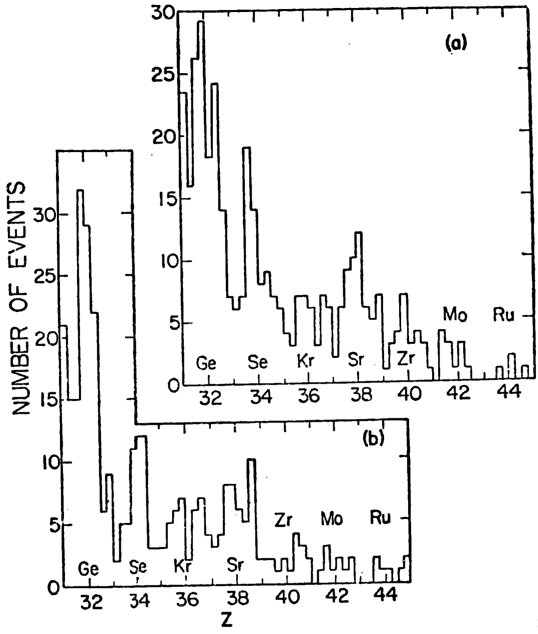
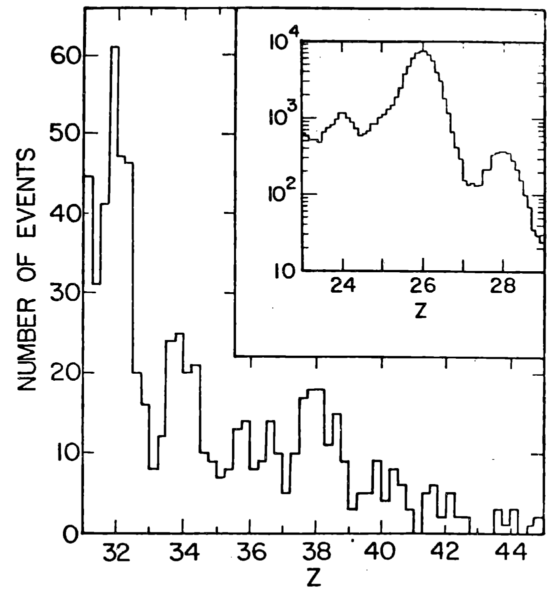


Figure 1

Charge histogram of
(a) "high rigidity" data
and (b) "low energy" data.

Figure 2

Charge histogram of
(a) combined "high rigidity" and "low energy" data for $23 \leq Z \leq 29$ and
(b) the corresponding data for $31 \leq Z \leq 45$.



The quoted errors for the even charge abundances in Table 1 include both statistical errors from the linear fit to a sum of gaussians and errors resulting from the uncertainty in the charge distribution which enters nonlinearly. Corrections to the best fit abundances for interactions within the instrument have not been made since our interaction rejection criteria widens with increasing charge, compensating for the increased probability of interactions at higher charges, leaving a residual correction of <5% over this charge region.

Table 1. Elemental Abundances Measured on HEAO-3

Even Z	Low E	High R	Low E + High R	CRS	Ariel VI	Odd Z	Low E + High R
26	10^6	10^6	10^6	10^6	10^6		
32	96^{+14}_{-10}	86^{+15}_{-17}	91^{+12}_{-8}	81^{+14}_{-9}	–	33	[9] < 19
34	39^{+9}_{-7}	47^{+14}_{-15}	43^{+9}_{-6}	33^{+11}_{-6}	83	35	[7] < 14
36	22^{+8}_{-5}	24^{+12}_{-10}	23^{+8}_{-5}	13^{+10}_{-5}	46	37	[9] < 16
38	28^{+9}_{-6}	36^{+16}_{-12}	34^{+10}_{-6}	33^{+12}_{-7}	48	39	[5] < 12
40			13^{+5}_{-4}	14^{+6}_{-5}	21	41	[3] < 6
42			8^{+2}_{-2}	7^{+3}_{-3}	11		

The observed results for LE and HR abundances are given in Table 1. These abundances show generally good agreement within statistics and have therefore been combined to obtain abundances with improved statistical significance. These abundances have been propagated backward through a 5.5 g/cm^2 (H) exponential pathlength distribution (Margolis, OG5.2-8) to obtain source abundances. Comparing these observed abundances with our earlier data (Binns, et al. 1981b) there is general good agreement within statistics with the exception of Germanium. The present lower abundance for Ge resulted from our identification of a small class of iron nuclei which were incorrectly identified as low energy nuclei with $31 \leq Z \leq 35$. Table 1 also shows the Ariel VI abundances (Fowler, et al. 1981) for this charge region which are generally higher than our abundances.

3. Conclusions

Figure 3a shows our observed abundances compared with solar system abundances (Cameron, 1982) propagated forward through a 5.5 g/cm^2 exponential PLD of hydrogen with (dashed line) and without (solid line) a first ionization potential (FIP) bias applied (Brewster, et al. 1983). With the exception of Ge and Rb which are volatile elements (Meyer, 1981) we see generally good agreement with the solar system abundances with FIP applied. While Rb (with FIP = 4.2 eV) is deficient compared to the FIP model used here (CRS/SS=9.31 exp(-0.288 FIP) it would not be deficient in a model where CRS/SS is independent of FIP for FIP < 8 eV (Meyer, 1981). However Ge has the same FIP as Fe, so our Ge/Fe observation disagrees with any FIP model.

A similar comparison with the Cameron Solar System r-process (Cameron, 1982b) with and without a FIP bias applied is shown in Fig. 3b. Our measured abundances are almost a factor of 5 greater than the r-process part of the SS abundances. If we permit an r-process enhancement by multiplying the predicted r-process abundances by a factor of 4.5 as shown in Fig. 3c, our even Z abundances roughly follow those from an r-process source with FIP. However the Cameron SS r-process with or without a FIP bias has more Rb than Sr for any conventional FIP function.

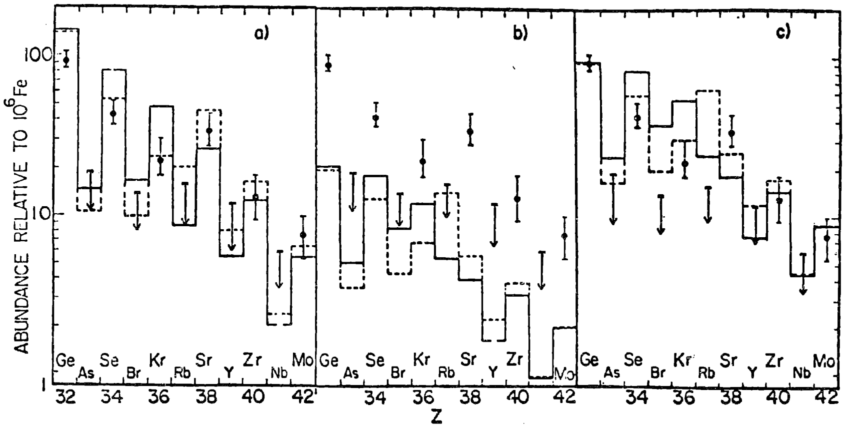


Figure 3. Comparison of our measured abundances with (a) SS abundances with and without a FIP bias (dashed and solid line respectively), (b) Cameron SS r-process abundances, and (c) Cameron SS r-process abundances enhanced by a factor 4.5.

Our data as shown in the histograms of Figs. 1 and 2, as well as our fitted abundance values, clearly show that there is more Sr than Rb present in the cosmic radiation. This is a strong indicator that the Cameron SS r-process is not dominant in this charge region.

Thus we conclude that the simplest interpretation of our result is that the cosmic-ray source has SS abundances modified by a FIP and/or volatility-dependent bias (Israel et al. OG6-39) in this charge interval.

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