ENERGY SPECTRA OF ULTRAHEAVY COSMIC RAYS RESULTS FROM HEAO-3

Israel, M. H., Jones, M. D., Klarmann, J., Binns, W. R.
Washington University, St. Louis , Missouri 63130, U.S.A.

Garrard, T. L., Stone, E. C.
California Institute of Technology, Pasadena,
California 91125, U.S.A.

Fickle, R. K., Waddington, C. J.
University of Minnesota, Minneapolis, Minnesota 55455, U.S.A.

ABSTRACT

The HEAO-3 Heavy Nuclei Experiment measures cosmic-ray energy directly in the interval 400 to ~1200 MeV/amu. Geomagnetic cutoffs can also be derived up to ~15 GV. We present preliminary rigidity spectra of various ultraheavy cosmic-ray elements relative to iron.

1. Introduction

The HEAO-3 Heavy Nuclei Experiment (Binns 1981) has collected information about the ultraheavy cosmic-rays (charge Z > 30) with greater statistics and resolution than previous detectors. In this paper we examine the rigidity dependence of abundances of various elements relative to Iron. Using a combination of Cerenkov counter and gas ion chambers we can assign unique charges and energies to most heavy CR particles which enter our detector with energies between 400 and 1200 MeV/amu. For higher energies, we use a simple Stormer model of geomagnetic cutoff to determine the minimum rigidity a particle requires to reach our detector at a given location from a given direction. This allows us to make selections of events with some minimum rigidity. When the sense of the trajectory is ambiguous we adopt the lower of the two possible cutoffs.

2. Data Selection

The data recorded for each cosmic-ray nucleus were required to meet several consistency requirements in order to be considered a valid event. Events were limited in geometry to those giving signals in at least one ionization chamber on each side of the Cerenkov counter. The trajectory as determined by the multiwire ionization hodoscope must be unambiguous. The ratio of Cerenkov signal to ionization signal must be in a physically meaningful range. The signals in the ion chambers must be consistent within an ion chamber module and between modules on each side of the Cerenkov detector. Specifically indications of charge-changing interactions within the detector of more than ~5% in charge (one charge unit at Fe) have been eliminated. Corrections to the abundances for interactions within the instrument have not been made since our rejection criteria for charge changing interactions of more than 1 charge unit offsets the interaction correction leaving a residual correction of <5% over this charge region. We also require that the spacecraft be outside of the South Atlantic Anomaly.

Data from 313 days starting in October of 1979 are included in this analysis. The data set from which these events were selected included all events of $Z > 30$ and 1/40 of all events with $Z \leq 30$ (selected at random from throughout the time interval). This one-in-forty subset was originally developed to use as a workable tool to normalize the higher charge events to Iron. For ratios of elements with $Z > 30$ to Iron, the precision is limited by the statistics of the higher charged elements. In this paper we also present abundances of $_{22}$Ti, $_{24}$Cr, and $_{28}$Ni relative to $_{26}$Fe; for these abundances the statistical precision is limited by the 1/40 factor.

3. The Data

The best charge resolution comes from "low energy" events with energies of ~400-1100 MeV/amu and "high rigidity" events with minimum rigidity cutoff of >8 GV. By dividing these data into four comparably sized sets limited relative rigidity spectra can be obtained. The cuts were made so that set 1 has rigidity of 2.9-3.5 GV(0.61-0.84 GeV/amu at ^{56}Fe). Set 2 has rigidity of 3.5-4.0 GV(0.84-1.08 GeV/amu at ^{56}Fe). Set 3 contains those events with observed cutoff rigidities of 8-10 GV. Set 4 contains those events with >10 GV cutoff.

We have used rigidity rather than energy as the independent parameter of our analysis because the geomagnetic field acts as a rigidity filter and the motion of the spacecraft gives us different exposure times for different rigidities. We have used a piecewise linear, monotonic function of Z as an approximation to Z/A in the conversion from observed energy per nucleon to rigidity.

For each of the four sets, individual element abundances were derived by fitting gaussians to charge peaks in a least-squares manner. These fit abundances are used for $Z \leq 32$. The charge group "34-42" was created by binning with assigned charges from 33.0 to 43.0. The "44-48" and "50-58" charge groups were constructed similarly.

Table 1 has abundance values for the charges 22, 24, 26, 28, 32 and the charge groups 34-42, 44-48 and 50-58 normalized to Fe. Figure 1 gives plots of relative abundances versus rigidity.

Table 1a : Abundances Relative to Fe ≡ 1000

Z	Rigidity 2.9-3.5 GV	Rigidity 3.5-4.0 GV	Cutoff 8-10 GV	Cutoff >10 GV
22	180±14	156±11	106±2	97±3
24	177±11	147±11	120±3	113±3
26	1000±28	1000±13	1000±7	1000±9
28	45±4	52±5	52±2	52±2

Table 1b : Abundances Relative to Fe ≡ 10^6

Z	Rigidity 2.9-3.5 GV	Rigidity 3.5-4.0 GV	Cutoff 8-10 GV	Cutoff >10 GV
32	108±23	71±19	75±13	85±17
34-42	150±23	98±18	141±13	155±16
44-48	$4\pm^{9}_{3}$	$10\pm^{10}_{6}$	14±4	12±5
50-58	31±10	$16\pm^{11}_{7}$	19±5	14±5

4. Conclusions

The results for the abundances relative to Iron of the Iron secondaries and of Nickel are in agreement with results reported by the Saclay - Copenhagen Collaboration(Koch-Miramond,Engelmann et al). The $_{22}$Ti and $_{24}$Cr relative abundances decrease with rigidity while the $_{28}$Ni relative abundance is insensitive to rigidity in accord with conventional propagation models. The results of the higher charges are new to this experiment.

None of the Z > 30 charge groups demonstrates a rigidity spectrum which is inconsistent with that of Iron within the statistical errors.

5. Acknowledgements

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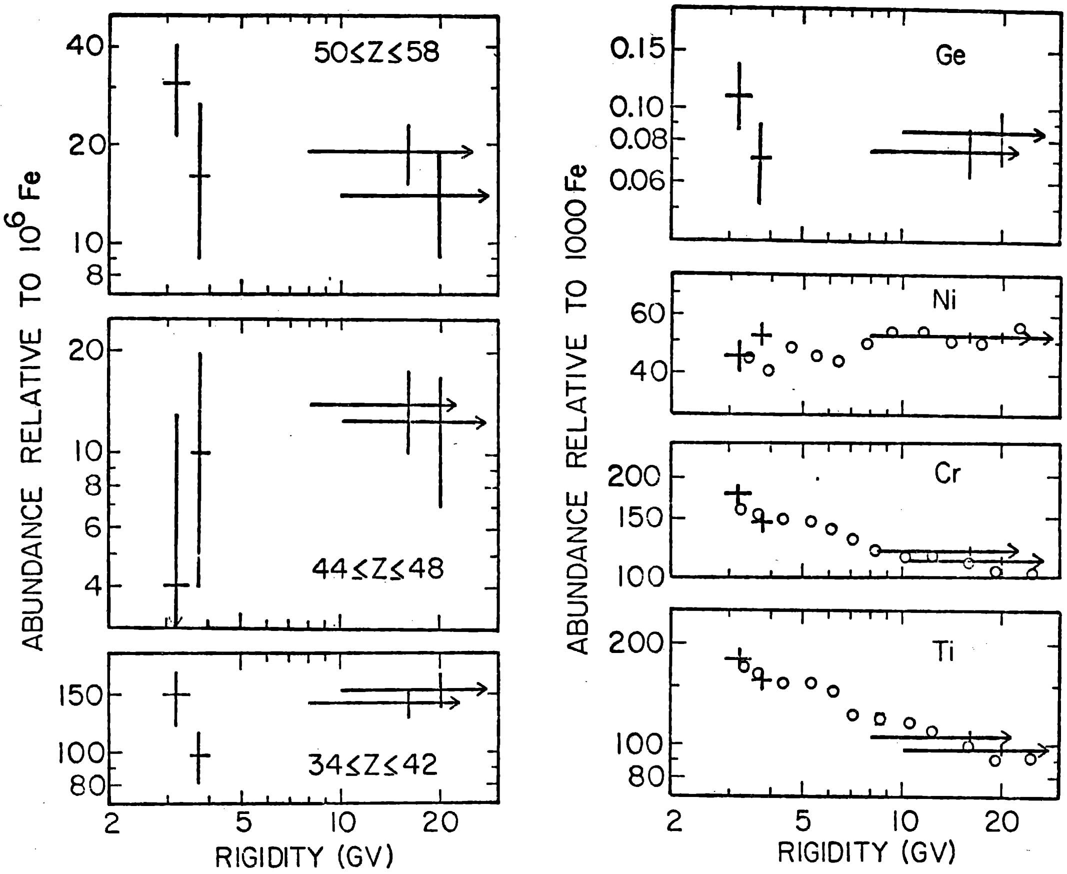

Figure 1: Relative abundances. + are our data; o are the data of the Saclay-Copenhagen Collaboration.

6. References

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