ABUNDANCE RATIOS FOR PRIMARY COSMIC-RAY NUCLEI FROM Be TO Fe FOR 5 TO 50 GV/c

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We present cosmic-ray abundances relative to carbon at 0 and 6 g/cm^2 of residual atmosphere, and ratios O/C and Fe/(C+O) as a function of rigidity for 5 to 50 GV/c. These abundances were measured with a superconducting magnetic spectrometer.

1. Introduction. A superconducting magnetic spectrometer was used to measure abundances of cosmic-ray nuclei above 4.5 GV/c over Palestine, Texas on September 30, 1972. A preliminary (Li+Be+B+N)/(C+O) ratio was presented as a function of rigidity at the 13th International Cosmic Ray Conference in Denver (Vol. 1, p. 177 and Vol. 5, p. 3557). Here we present preliminary results for the measured abundances relative to carbon, and for the O/C and Fe/(C+O) ratios as a function of rigidity. The O/C and Fe/(C+O) ratios have been previously reported to vary (Ormes et al. 1973, Juliusson 1973, and Juliusson 1974).

2. Apparatus. The apparatus has been described previously (Smoot et al. 1973). Four scintillators (S1-S4, top to bottom) and three optically viewed spark chambers (SC1-SC3) defined the geometry (0.11 m^2 sr). An anticoincidence scintillator placed on the face of the magnet dewar vetoed events involving interactions in the mass of the magnet-cryostat system. The veto was excluded for charges $Z > 6$ in S1, however, to eliminate a bias against good highly charged events which produced many delta rays. The instrument was flown to an altitude of 35.5 km (5.5 g/cm^2) for a live time of 7 hrs. Sixty-six thousand pictures were taken which recorded the spark locations and digitized scintillator pulse height data on 35 mm film.

3. Data Analysis. The photographs were scanned and forty-five thousand were found to have non-interacting single-particle topologies in the spectrometer. The film was measured by a semi-automatic measuring machine with an effective measurement error in real space of 0.2 mm per spark chamber. The rigidity (p/Z) for each event was determined by fitting an acceptable trajectory to the measured spark locations in the usual manner (Smith et al. 1973); the resulting resolution was about 0.02 c/GV in Z/p, after corrections for camera lens distortion (Smoot et al. 1973). The semi-automatic measuring machine also decoded the digitized pulse height data.

Photomultiplier saturation and scintillator spatial non-uniformity were removed from the pulse height data through empirical corrections which used C, O, and Fe flight data. The spatial corrections were typically a few percent with maximum of 10 to 15 percent. The empirical correction for one scintillator was verified by a test in the heavy ion beam at the LBL Bevatron. The phototube saturation curves were also checked with a calibrated light source and were found to have the same functional form within an overall normalization parameter. The resulting scintillator resolution was about 0.3 charge units at carbon but worsened to about 0.8 by iron. The total charge resolution from the four scintillators is displayed in figure 1. Here we plot $\chi^2 = \Sigma(\sqrt{PH} - \langle Z \rangle)^2$ vs $\langle Z \rangle$, where PH is the pulse height for each scintillator and $\langle Z \rangle$ is the average charge based on all four pulse heights.

4. Charge Selection. To avoid introducing systematic error in selecting the charge for each event, various selection techniques are now under study. For the results presented here, we first established the charge on the basis of S1 alone, and determined the abundances for Be-Fe relative to C. For comparison, we then chose the charge on the basis of S1 and S2, and corrected the resulting abundances for fragmentation and scintillator resolution effects. For the S1-S2 selection, an acceptable event was required to have each pulse height within one-half charge unit of the selected integer charge. Because of the worsened charge resolution for iron, we added all events having S1 and S2 within 2.5 charge units of 26. For P→Cr, we required S1 and S2 to be between Z = 15 and Z = 24. The remaining charge bias was removed with a Monte Carlo program considering the following: 1) the scintillator resolution as a function of Z, 2) the latest fragmentation cross sections for Z = 6, 8, and 18 (Lindstrom et al. 1975a, 1975b), 3) the semi-empirical fragmentation relations of Silberberg and Tsao (1973), and 4) our own estimates of nucleon-stripping effects. These corrections, to be described in detail elsewhere, adjusted the S1-S2 abundances to a level just above S1. Agreement with the S1-selected abundances was satisfactory. Corrections to the top of the atmosphere through 6 g/cm^2 of air were also made.

5. Results. The results as a function of rigidity are shown in figure 2 for two abundance ratios. The relative abundances for the integral flux above Palestine geomagnetic cutoff (~4.5 GV/c) are shown in Table 1. Most of the abundances are consistent with those measured with our first-generation gondola (Smith et al. 1973). Some changes have resulted (e.g. in Be) from improved fragmentation data.

The Fe/(C+O) data presented in figure 2 disagree with the steep rise reported by Ormes et al. (1973), but agree with the more gradual (and consistent with zero) rise measured by Saito et al. (1974). Our O/C data tend to support the claim of Juliusson (1973, 1974) that this ratio rises slightly with increasing rigidity, but are also consistent with zero rise.

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TABLE 1: COSMIC-RAY ABUNDANCES RELATIVE TO CARBON (PRELIMINARY)

	Be	B	C*	N	O	Ne	Mg	Si	P-Cr	Fe
AT GONDOLA ($6\ g/cm^2$)	12 ±2	28 2	100 2	24 2	92 2	18 2	22 2	16 2	13 3	12 2
TOP OF ATMOSPHERE ($0\ g/cm^2$)	8 ±2	23 3	100 3	21 3	98 3	18 2	24 2	19 2	14 4	15 3

* Absolute carbon flux (at gondola) above Palestine cutoff (~4.5 GV/c) = $2.0 \pm 0.1\ m^{-2}sr^{-1}sec^{-1}$

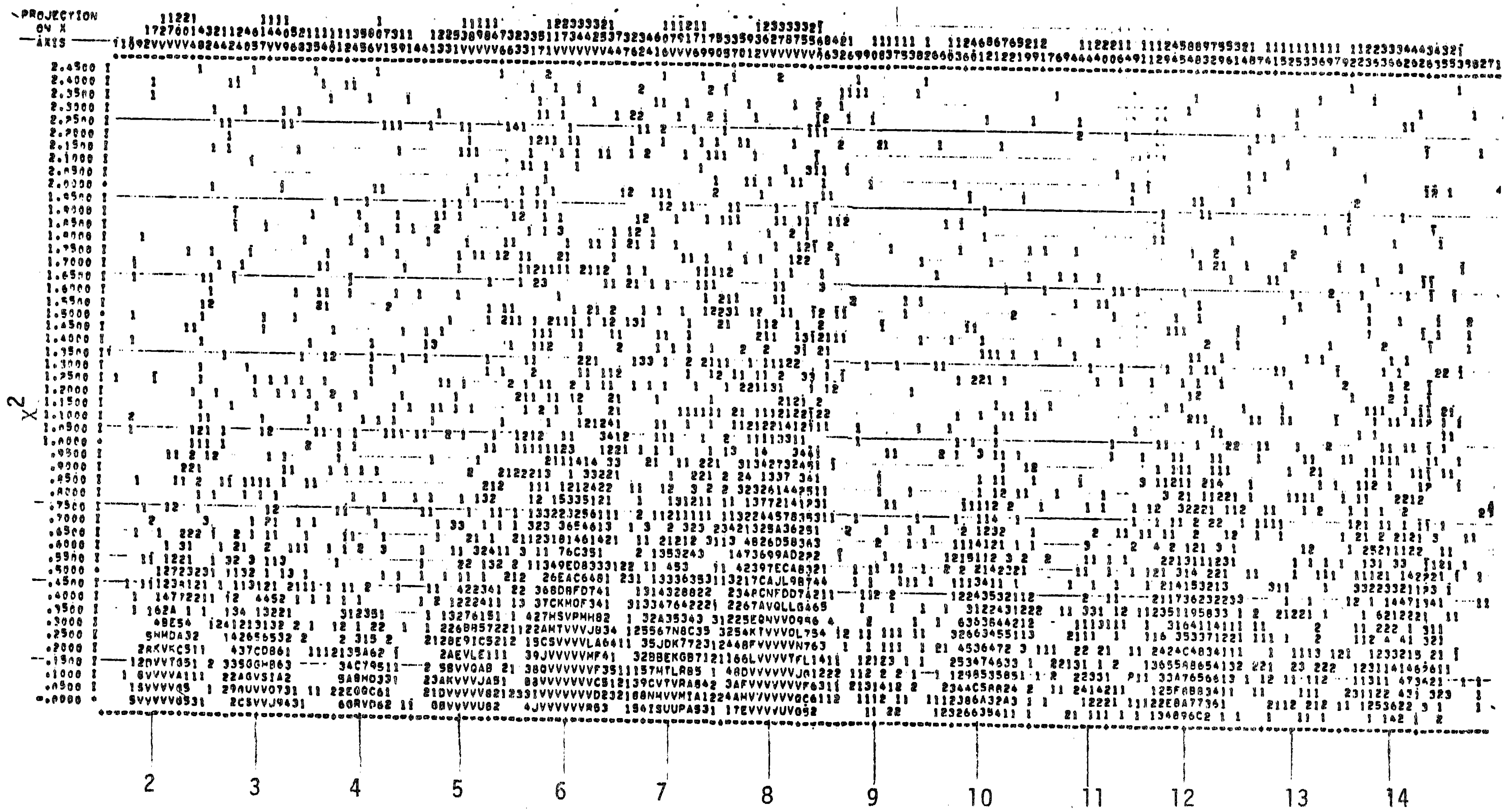

FIGURE 1: Plot of χ^2 From Average Charge Versus Average Charge. The average charge, $\langle Z \rangle$, is computed as the average of the square roots of the pulse heights, PH, in four scintillators; and $\chi^2 = \Sigma(\sqrt{PH} - \langle Z \rangle)^2$. A V on the scatter plot indicates more than 31 events.

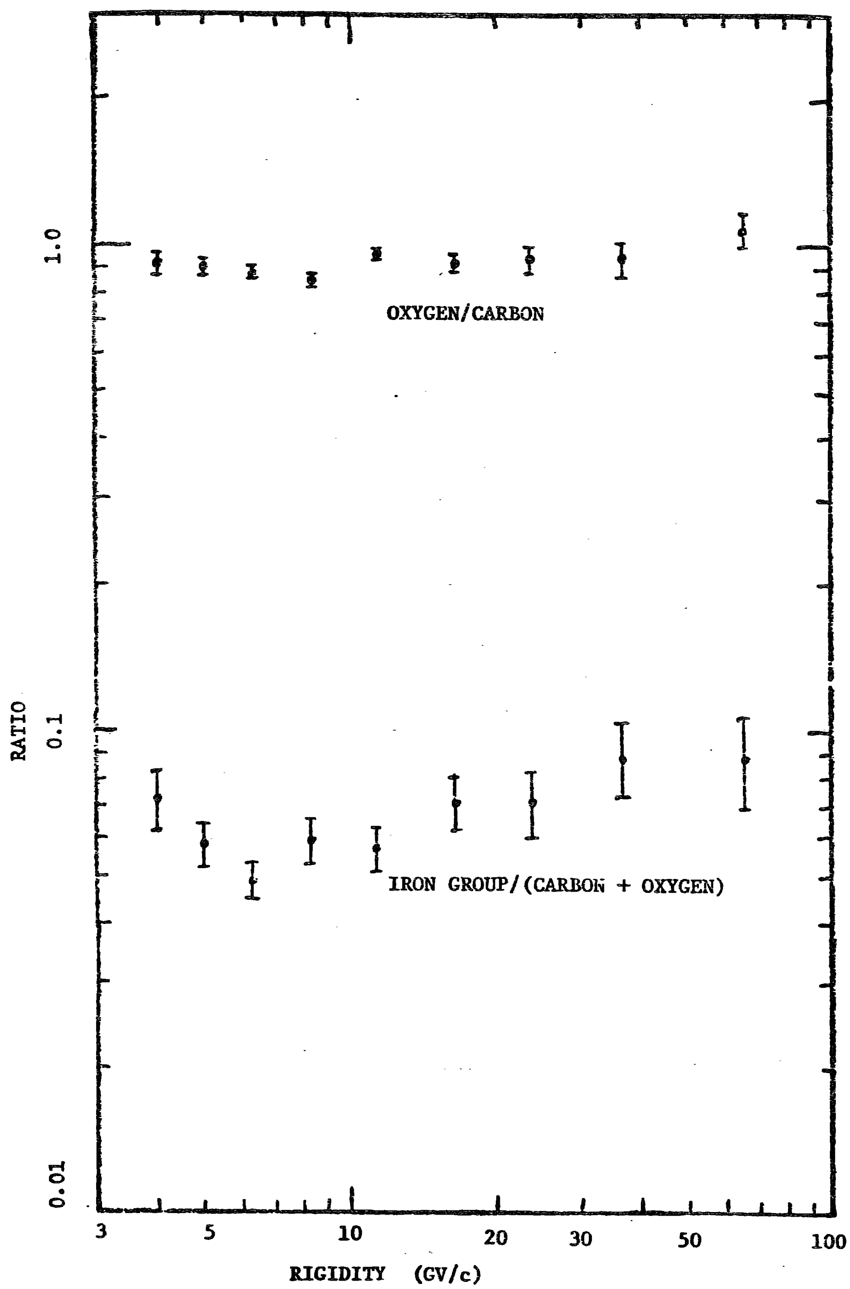

Figure 2. Plots of the ratios OXYGEN/CARBON and IRON GROUP/(CARBON+OXYGEN) as a function of rigidity. Errors shown are statistical only, and the ratios have not been corrected for about 6 g/cm^2 of overlying atmosphere.