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AN INTERPRETATION OF THE CARBON-OXYGEN TO IRON RATIO

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Data from recent measurements on the composition of primary cosmic rays above 1 GeV/nucleon is critically reviewed for information pertaining to selection of suitable energy dependent composition models. Areas where crucial experimental information may result in selection of a suitable model are pointed out. In particular, the study of energy distribution of V.V.H. nuclei, and obtaining more accurate energy spectra of $10 \le Z \le 14$, $15 \le Z \le 23$ and $Z > 24$ would contribute to discriminate between models which rely on interstellar propagation and those that ascribe a different source mechanism for Fe group nuclei.

1. Introduction. Many recent experiments (Juliusson et al., 1972, Smith et al., 1973, Webber et al., 1973 Ormes and Balasubrahmanyan, 1973) have demonstrated rather dramatic changes in the composition of cosmic rays above a few GeV/nucleon. Though quantitative differences exist among different experimenters, the two central facts on which there is reasonable agreement are 1) the secondary component of cosmic radiation (Li, Be, B, etc) become less abundant at high energies and 2) the relative abundance of the Fe group of nuclei relative to the other primary nuclei C, O increases with energy.

Attempts to explain this difference can be broadly classified into two groups. The first explanation relies on interstellar propagation models (Webber et al., 1973, Audouze and Cesarsky, 1973, and Meneguzzi, 1973) to explain these observations. The second explanation (Ramaty et al., 1973) is based on the proposition that a major fraction of the Fe nuclei are accelerated in a source different from the rest of the cosmic rays. At the moment the experimental uncertainties do not permit a clearcut discrimination of either alternative to the exclusion of the other. In this discussion, an attempt is made to present recent data on the subject and our suggestions regarding future experimental observations for more definite conclusions on this problem.

2. Energy Spectra of the Elements

In Figure (1) the exponents of the power law spectra of the primary elements in cosmic rays H, He, C, O, LH group and the Fe group and its secondaries ($15 \le Z \le 23$) are shown. The Berkeley and Goddard groups have measured the differential spectra using magnetic and ionization spectrometers. As can be seen up to Z = 14 (up to which the Berkeley group's published work gives power law exponents) the agreement between the two results are excellent. The
It appears from Figure (1) that the exponent takes a sudden dip from ~ 2.5 to ~ 2 beyond Z = 14. The difference between the spectral exponents of secondary nuclei, (Li, Be, B and N) and their primary progenitors (C, N, O), $\Delta\gamma \sim .2$ is also in reasonable agreement with the results of the two group.

The secondaries from Fe also show $\Delta\gamma \sim .2$. Though the results may be consistent with a sudden change in γ beyond $Z>14$, the large statistical errors on the nuclei $Z>14$ may not exclude a gradual change in γ with Z. Results for nuclei with $Z>30$ are very scarce. For $Z>60$ in energy range 5000 MeV/nucleon to 2 GeV/nucleon (where all nuclei usually have appreciable flatter energy spectra) Osborne et al., (1973), find a $\gamma = 5.5^{+1.1}_{-1.0}$, a very steep spectrum, inconsistent with a gradual change in spectrum with Z. A crucial measurement to help resolve this are, (1) the measurement of the energy distribution of V.V.H. nuclei and (2) the attainment of greater accuracy in the measurement of γ of nuclei with $Z>14$.

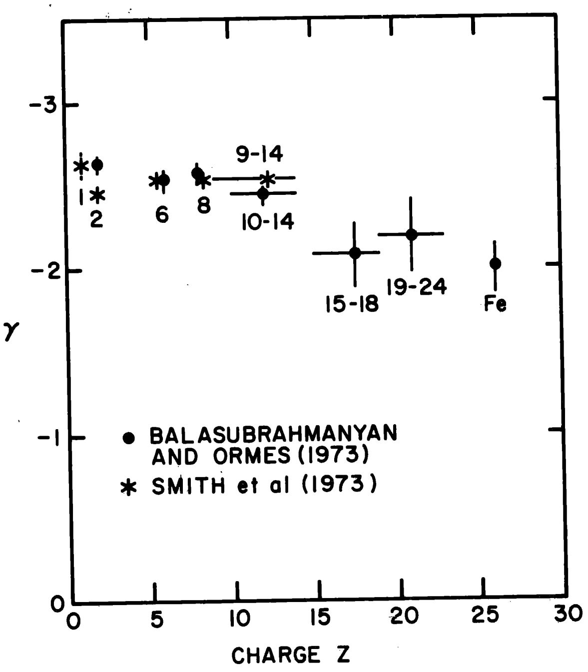

Figure 1. Exponents of Energy Spectra vs. Charge

3. Relative Abundance of Iron and Its Secondaries.

The experimental situation for nuclei $Z>14$ is shown in Figure (2). The data of Smith et al., 1973 have been extrapolated to the top of the atmosphere using the same technique applied to the Goddard results. In energy range 1 to 10 GeV/nucleon, the two groups seem to agree on a ratio $(15 \leq Z \leq 23)/(Z>24) \sim 1.25$. Webber et al., 1973, however find that the ratio $(17 \leq Z \leq 25)/(Z>25)$ decrease by a factor > 3 in the energy range 1 to 10 GeV/nucleon. Webber et al, remark that the drop in this ratio is too rapid compared to the change in Li, Be, B/C+O over this energy range. Better measurements in this charge range are needed for resolving this contradiction.

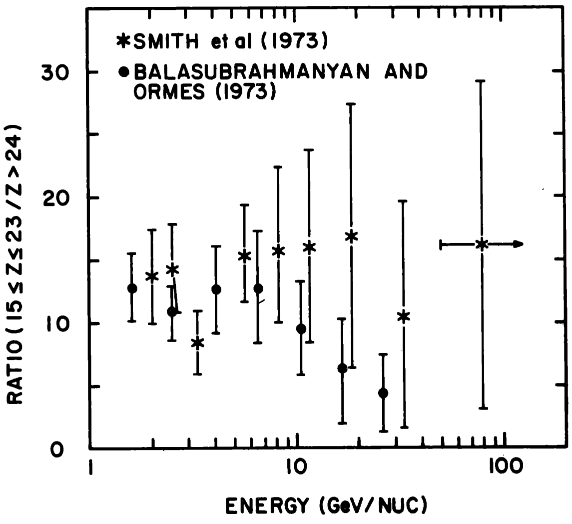

Figure 2. Relative Abundances of Nuclei $15 \leq Z \leq 23$ vs. Energy

4. Ratio C+O/Fe.

Figure 3 shows the compilation of results on the ratio C+O/Fe group. The evidence for the decrease of this ratio with energy is quite strong. The Goddard results seem to be the lower bound whereas the Berkeley results define the upper bound of the large spread in values. But the errors (mainly statistical) are large and clearly point to more experiments to decrease the spread so that more accurate trends could be established. With these in mind, we are planning a series of balloon flights to obtain more precise data, to resolve the problem.

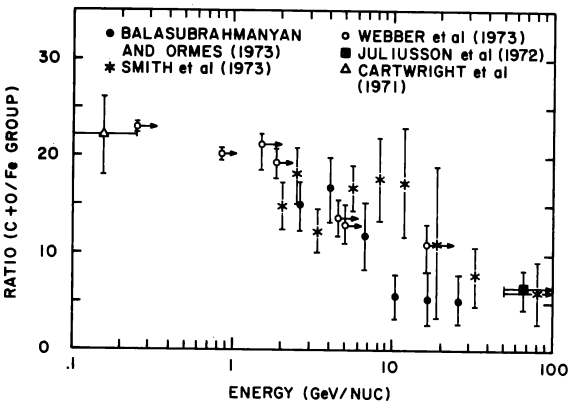

Figure 3. Ratio C+O/Fe vs. Energy

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