Chemical Composition of Heavy Cosmic Ray Nuclei Above 5 GV

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Using improved instrumentation similar to that described at the 1970 COSPAR meeting, new results have been obtained on the abundance ratio of elements between atomic numbers 4 and 30.

Summary of Paper

1. Instrumentation.

Fig. 1 and 2 show the essential features of the instruments used. Cerenkov counters with radiators of different refractive index (i.e. with different response to variations in the particle velocity) are used to determine the charge and velocity of the particles; the method is discussed in detail by Corydon Petersen et al. (1970).

Pre-flight calibration data are used together with the trajectory of each particle, which is recorded during flight, in order to improve the charge and velocity resolution. The spark chamber information is also an aid in the rejection of nuclear interactions. The Saclay-DSRI instrument used three Cerenkov counters and a 14 gap, plate spark chamber with photographic recording. The DSRI instrument used only two Cerenkov counters in its first version and three in the later versions. Wire spark chambers with electronic read out are used here (3 gaps). The geometry factors are ~120 cm²st, and ~230 cm²st for the Saclay-DSRI and the DSRI instrument respectively.

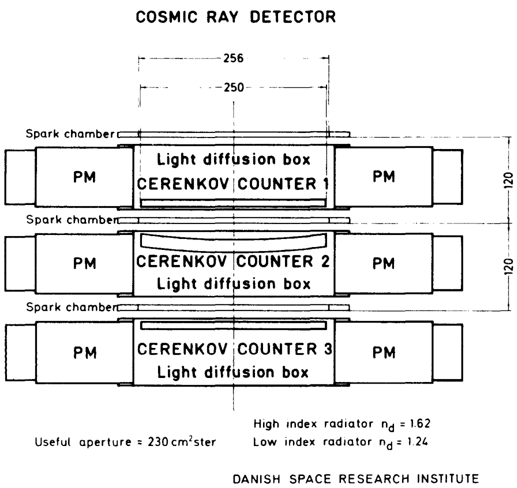

Fig. 1.

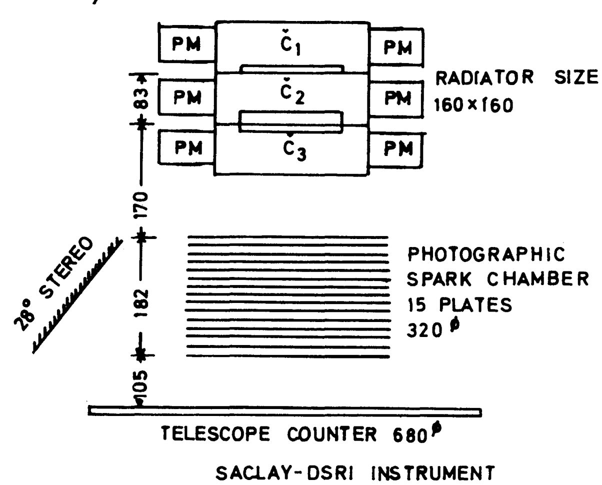

Fig. 2.

2. Analysis of Data.

From the raw data a first selection is made by demanding a unique straight trajectory passing through the counters to be defined by the spark chamber data. These primary data still contain many events in which the heavy nucleus made an interaction in traversing the instrument. Three further criteria were used alone and in combination in order to obtain clean data. (PH 1, PH 2, and PH 3 designate in the following the corrected pulse heights from the first glass counter, the liquid counter, and the second glass counter respectively).

I Rejection by the redundant glass counter (demanding that the ratio PH 1/PH 3 lies within specified limits). This is a very efficient way of rejecting interactions. Unfortunately, the data from the two first flights of the DSRI instrument do not permit such a selection to be made because this instrument had no redundant glass counter.

II Rejection by the spark chamber information.

a) Rejection by the number of sparks (demanding that the total number of sparks in the three spark chambers does not exceed a specified number). This selection was found to be particularly useful in the region of the lowest charges, $Z \lesssim 5$. (Wire spark chamber only).

b) (Multi-plate, photographic spark chamber only). The plate spark chamber is insensitive to knock-on electrons when a heavily ionizing particle is present simultaneously. The demand is that only one track is visible in the first four gaps. If several tracks are seen in gaps 5 to 14, the event is rejected if the convergence point of the tracks is higher than the fifth plate.

III Rejection by consistency with the geomagnetic rigidity cut-off. (Demanding that the ratio PH 2/PH 1 exceeds the value corresponding to the lowest velocity particles allowed by the cut-off). Allowance must be made, of course, for the fluctuations in the velocity measurements. This criterion was always applied last; in fact, the importance of the other two criteria was estimated by observing how many events were left for the third to remove. This is relevant because nuclear interactions usually result in a too low velocity estimate for the particle.

The quality of the resultant data as regards interaction background is illustrated by the fact that for one of the DSRI flights the fraction of events left for criterion III was 18% in the primary data; it dropped to 2% after application of criterion I and to 0.8% when both I and II were used. In the case of the Saclay-DSRI instrument 80% of the known interactions are detected by both criterion I and II b. 10% are detected by I and not by II b, and 10% by II b and not by I.

3. Results.

Two charge histograms corresponding to a part of the data are shown in Figs. 3 and 4. The combined results of all the flights are presented in table I. Since the events rejected due to interaction are a large fraction of the total (because of the large amount of matter in the instrument), our results give relative abundance of elements within a charge group; the fluxes of elements having very different charges cannot be compared directly because of the significant differences in the fractions rejected.

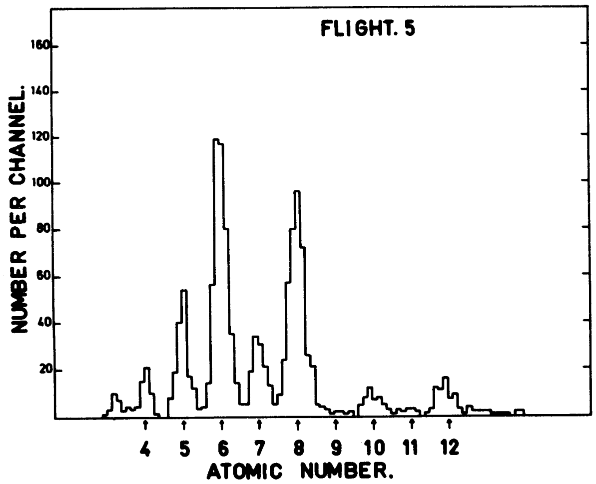

Fig. 3.

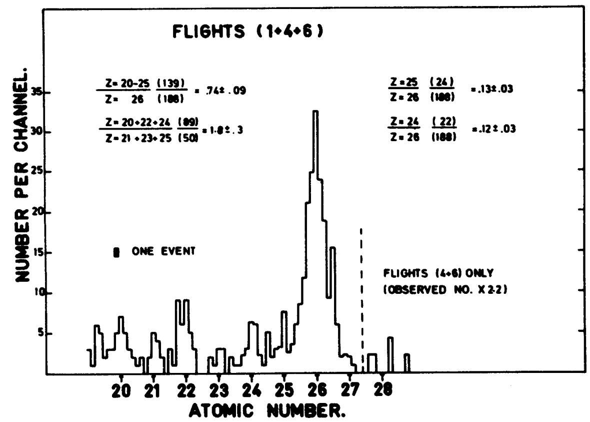

Fig. 4.

4. Extrapolation to the top of the atmosphere.

Our results correspond to a weighted average atmospheric depth (including the matter above the first counter in the instruments) of 5.9 g/cm . We divide all elements into two groups: group A of elements heavier than Si and group B of the lighter elements. Contribution of group A to group B has been neglected. Fragmentation parameters are assumed to have 1/3 of their value in Hydrogen for group A, and the same values as in Hydrogen for group B. The fragmentation parameters in Hydrogen are taken from ref. (2) for nuclei between Si and Fe and from ref. (3) for other nuclei.

These authors have given the parameters for the interstellar conditions and therefore some of the parameters could be quite far from those applicable to the atmosphere. The correction due to secondary production and the flux values at the top of the atmosphere are given in columns III and IV respectively of table I.

5. Discussion.

Calculations have been made for an interstellar propagation corresponding to an exponential path length distribution of potential path lengths with a mean of 5 g/cm^2. The results show that most of the observed Aluminium and part of the Nitrogen nuclei originates in the cosmic ray sources.

The observed low flux of Chromium and Manganese limits the amount of Iron spallation products possible for the lighter elements. The calculations indicate that, in order to reproduce the observed fluxes of the elements from Sulphur to Titanium, some source contribution must exist in this charge range. However, the statistical weight and the resolution of the observational data are still marginal.

Table 1

Nucleus	Observed Number	Atmosphere Production	Extrapolated No. at the top of the atmosphere	Ratio at the top of atmosphere
Be	100	19	91 ± 11	Be/C = .13 ± .02
C	625	22	694 ± 29	
B	458	91	417 ± 24	B/C = .28 ± .02
C	1316	53	1460 ± 41	C/O = 1.03 ± .04
O	1222	15	1420 ± 45	
N	456	87	432 ± 25	N/O = .24 ± .02
O	1567	20	1820 ± 46	
F	44	10	41 ± 8	F/Ne = .15 ± .03
Ne	237	17	265 ± 20	Ne/O= .15 ± .01
Ne	407	28	455 ± 24	Ne/Si= 1.02 ± .08
Na	89	17	87 ± 11	Na/Mg= .16 ± .02
Mg	452	15	533 ± 26	Mg/Si = 1.19 ± .07
Al	129	11	146 ± 14	Al/Si = .33 ± .04
Si	362	neglected	449 ± 24	
				Relative to Fe:
P	20	2	23 ± 5	.09 ± .02
S	51	3	63 ± 9	.23 ± .04
Cl	13	1	15 ± 5	.06 ± .02
A	21	3	25 ± 6	.09 ± .03
K	31	2	39 ± 8	.14 ± .03
Ca	31	2	39 ± 8	.14 ± .03
Sc	14	1	18 ± 5	.07 ± .02
Ti	36	4	45 ± 8	.17 ± .03
V	12	2	14 ± 5	.05 ± .02
Cr	22	4	25 ± 7	.09 ± .02
Mn	24	2	32 ± 7	.12 ± .03
Fe	188		269 ± 20	
Fe	85			
$Z \geq 28$	5			.06 ± .03

Note: The horizontal lines separate data not obtained in the same flights.

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