ON THE CONSTANCY OF COSMIC RAY COMPOSITION IN THE PAST

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Abundances of heavy nuclei (Z$\geq$30) in cosmic rays are sensitive to their source composition and acceleration mechanism. In case the cosmic rays originate from local discrete sources at various stages of their evolution and as the solar system passes through the arm and interarm regions of the galaxy , a time variation in fluxes of heavy nuclei and their relative abundances may be observable at the earth. The nuclei 30$\leq$Z$\leq$40 are mainly produced in r and s process from seed nuclei of the iron group (20<Z$\leq$28). The ratio (30$\leq$Z$\leq$40)/(20<Z$\leq$28) may therefore be a suitable indicator for identifying nucleosynthetic processes in the source and acceleration characteristics of cosmic rays.

With this objective in view, we have studied the relative abundances of VVH/VH nuclei in galactic cosmic rays as a function of time. Olivine crystals irradiated to cosmic rays during different epochs were selected from a variety of meteorites and lunar rocks and dust and were studied using the fossil track techniques developed in our laboratory. The lunar rocks provide recent (0-2 m.y.) integrated record whereas grains from well stratified lunar cores, which are known to accumulate sequentially with time, (1,2), provide samples irradiated to brief spans of time (effectively 10^5-10^7 years) over the last one billion year. Data for the remote past were obtained from the track-rich grains of the meteorite staroe-Pesynaoe (4) which might be characteristic of cosmic ray irradiation 4.5 b.y. ago. Cumulative long term data upto 60 m.y. before present for meteorite orbits (1-3 A.U.) were obtained from olivines in Patwar and Itzwisis meteorites.

In this study we have confined to cosmic rays of energy >20MeV/n as above this energy the solar cosmic ray contributions are unimportant(3). Therefore, surface regions of samples showing solar flare contribution, as inferred by characteristic depth dependence (x^{-1}) were excluded from this study.

Experimental techniques are similar to those employed earlier(4). Olivine grains were etched using WN etch and VVH tracks (longer than 20 microns) and VH tracks (longer than 1 micron) were counted. Suitable corrections for etching efficiency of VH and VVH tracks, for erosion (assumed to be 5×10^{-8} cm/ y), mean path length and different ranges of VVH and VH

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nuclei have been taken into account(3) in calculating the abundance ratio.

The results are presented in figure 1. The scatter is somewhat larger than the statistical errors. However, it can be seen that the ratio (VVH/VH) has remained similar within a factor of two over the whole time period studied. The observations suggest that the cosmic ray sources are remarkably similar in their heavy nuclei abundances or that these nuclei spend enough time in the galaxy to get well homogenised. No differences between meteorite orbits (1 to 3 A.U.) and 1 A.U. are discernible at energy>100 MeV/n where observations have been made.

As shown in fig 1, no significant variation in VVH/VH ratio with energy between 30 to 2000 MeV/n is observed, although a slight increase (50%) at 50-100 MeV/n is indicated for the last 2 m.y. based on observations in a lunar rock. If this is supported by further observations, it would imply that the energy spectra of VH and VVH nuclei are different in this narrow energy range, which may in turn reflect upon acceleration mechanism in the source and modulation in the interplanetary space. In this context it should be noted that the solar abundance of VVH/VH is 2.1×10^{-3} whereas in the solar cosmic rays due mainly to the flare acceleration mechanism, values upto 13.4×10^{-3} have been observed(3).

The measurements are very sensitive to the abundance of Zinc (Z = 30), which is the most abundant nuclei in the VVH group. The relative abundance of these nuclei, VVH/VH is more than a factor of four lower in r-process than that expected in the s-process synthesis (5). The observed data are discussed in light of the various models of origin of cosmic rays in Supernovae and massive stars(6, 7).

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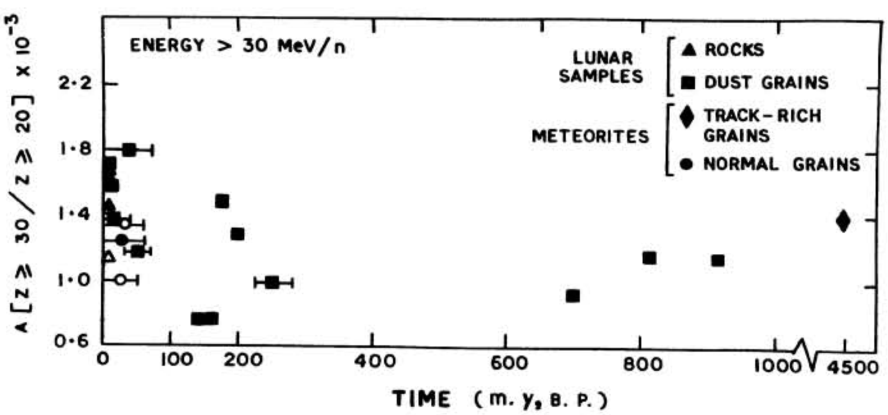

FIG. 1

Caption to Fig. 1:

Observed abundance ratio of $Z \geq 30$ relative to $Z > 20$ nuclei in cosmic rays in the past. The bar on each point represents the time span over which the sample was irradiated to galactic cosmic rays. The typical error on each ratio is $\pm$ 20%. The irradiation time for lunar dust is model dependent(1) and could have errors of $\pm$ 20%, increasing cumulatively in the past. The open points represent data at high energy (E = 0.2 to 2 BeV/n) and the filled points at Energy 0.03 to 0.2 BeV/n. The ratio VVH/VH seems to be energy independent within a factor of two in this range.

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