ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

ДУБНА

E7 - 10667

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AVERAGE ABUNDANCES OF GALACTIC COSMIC RAYS WITH Z > 50 FROM STUDIES OF METEORITIC OLIVINES

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AVERAGE ABUNDANCES OF GALACTIC COSMIC RAYS WITH Z > 50 FROM STUDIES OF METEORITIC OLIVINES

Submitted to the 15th International
Conference on Cosmic Rays
(Plovdiv 13-26 August, 1977)

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Усредненные по времени распространенности галактических космических лучей с $Z > 50$, полученные при исследованиях оливинов из метеоритов

Представлены результаты исследований галактических космических ядер по трекам, создаваемым ими в оливинах из метеоритов Марьялахти, Игл Стейшн. Измерено более 3000 треков длиной свыше 140 мкм (область $Z \geq 50$). В предположении, что области длин следов 740-900 мкм соответствует группа ядер урана-тория, получено удовлетворительное согласие распространенностей галактических космических лучей и элементов солнечной системы в диапазоне атомных номеров Z от 50 до 92.

Работа выполнена в Лаборатории ядерных реакций ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1977

Perelygin V.P. et al. **E7 - 10667**

Average Abundances of Galactic Cosmic Rays with $Z>50$ from Studies of Meteoritic Olivines

By applying the selective etching technique to olivines from Marjalahti and Eagle Station meteorites over 3000 tracks longer than 150μm have been found to be due to galactic cosmic ray nuclei with $Z>50$. The data on the track distribution are compared with the known values of the relative abundances of the $50<Z\leq92$ elements in the solar system. Satisfactory agreement is obtained assuming the group of the longest 720-900μm tracks to correspond to the Th-U nuclei.

The investigation has been performed at the Laboratory of Nuclear Reactions, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1977

I. INTRODUCTION

Studies of the atomic number distribution and energy spectra of the VVH component of galactic cosmic rays are extremely complicated due to the low intensity of this component, about $4x10^{-4}$ of the intensity of the Fe group nuclei.

Systematic studies of VVH nuclei were initiated in 1967 by Fowler et al.[1] who carried out experiments using nuclear emulsion stacks exposed in ballones in the upper layers of atmosphere. Since 1969 similar studies have been performed by the groups of Fowler, Price, Walker and Fleischer with nuclear emulsions, polymer foils and Cherenkov detectors[2].

However the total exposure time for the 100 years of these intensive studies does not exceed 3-4 m^{-2} year sr. To increase considerably the sensitivity of such investigations one should expose in space for a long time tens and hundreds of square meters of nuclear track detectors.

Another method of investigating the VVH component of cosmic rays makes use of the capability of extraterristrial silicate minerals to detect and record for several tens and hundreds of million years the tracks of galactic nuclei with $Z > 20$[3].

Simple estimations show that one cubic centimeter of silicate crystals from the surface layers of the meteorites having an exposure age of 10^7- 10^8 years contains hundreds and thousands of tracks due to the thorium-uranium nuclei [4]. However in the previous studies of hyperstenes from Johnstown meteorite [5] and lunar pigeonite [6] only three tracks of Z>80 nuclei have been identified. However the total number of the tracks of VVH nuclei measured in refs. [5,6] is only several times smaller than the number of the tracks revealed in experiments based on the direct recording of galactic cosmic ray nuclei.

II. STUDIES OF THE TRACKS OF VVH NUCLEI IN OLIVINES

Here we present the results of our studies of the tracks of VVH nuclei in silicate crystals from meteorites, obtained since 1974 [4]. The aim of these experiments has been to increase significantly the experimental sensitivity to the VVH component of galactic cosmic rays.

The studies were carried out using transparent homogeneous crystals of olivines from pallasites. Olivine makes 70% of the pallasite volume, the crystal size usually amounting to several millimeters.

At the first stage of these studies a total of over twenty pallasites have been examined and a few samples located very closely to the preatmospheric surface of these meteorites have been found [7-10]. In these latter papers it has been shown that Lipovsky, Marjalahti, Pavlodar and Eagle Station meteorites have locations with the density of Fe group tracks of 10^6- $1.5x10^7$ per cm^2 of olivine crystals.

The studies of the tracks due to VVH nuclei required a significant improvement[10] of the etching technique proposed by Krishnaswami et al.[11], the umambiguous identification of these tracks against the background of dislocations and capillar inclusions[12], the calibration of meteoritic olivines with accelerated ions ranging from Ti to Kr and Xe[10,13], and the detailed studies of the thermal fading of old and new tracks in these crystals[8,9].

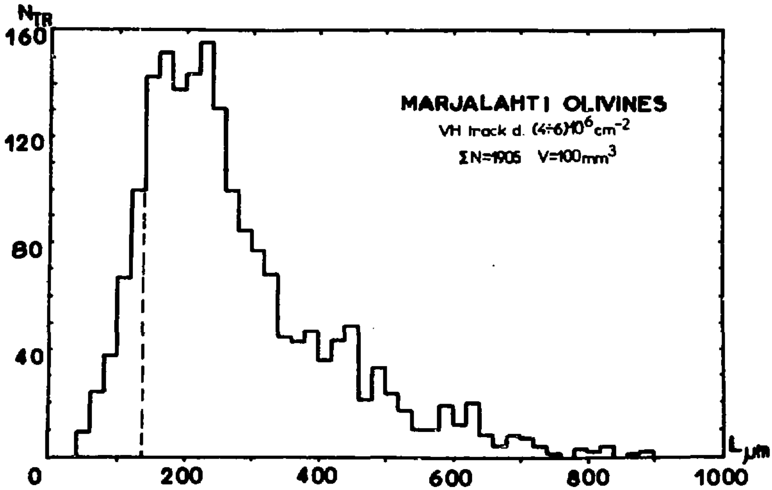
Our previous studies of the VVH tracks detected in 62 mm^3 of olivines from the surface layers of Marjalahti meteorite, carried out in 1976, permitted the determination of the relative abundances of the Z>50 nuclei, averaged over the exposure age of this meteorite equal to 175 million years[10]. The present investigations of olivines from Marjalahti and Eagle Station meteorites are an extension of these studies. We have selected, mounted in epoxy and polished over 600 crystals ≥ 2 mm in size of olivine from Marjalahti meteorite. The crystals had the density of the VH nuclei tracks of $(4-6)x10^6$per cm^2.We have also examined several dozens of 1 mm crystals of Eagle Station meteorite with a density of VH nuclei tracks of $(5-15)x10^6$ per cm^2.

The etching of these crystals was carried out in hermitically closed ampules at 100-110° C for a period of several days (refs.[8,10]). In the crystal volume tracks of VVH nuclei were revealed in natural cracks, capillar inclusions and dislocations inside the crystals[10]. Olivines without such structural defects were irradiated perpendicularly to their surface with 7.3 MeV/nucl. Xenon ions, or with ^{40}Ar and ^{40}Ca ions with a fluence of $10^{14}\,cm^{-2}$ and energy of 300 MeV through several slits with a 15-20μm width and 150-200μm spacing. Such a procedure permitted a rather efficient revealing of VVH tracks inside the crystal volume.

The microscopic examination of the crystals and measurement of the tracks were done at a magnification factor of 500-1500 X. All the tracks longer than 40μm were measured. To reveal the total etchable length of the inner tracks, the repeated etching of the crystals was used[10].

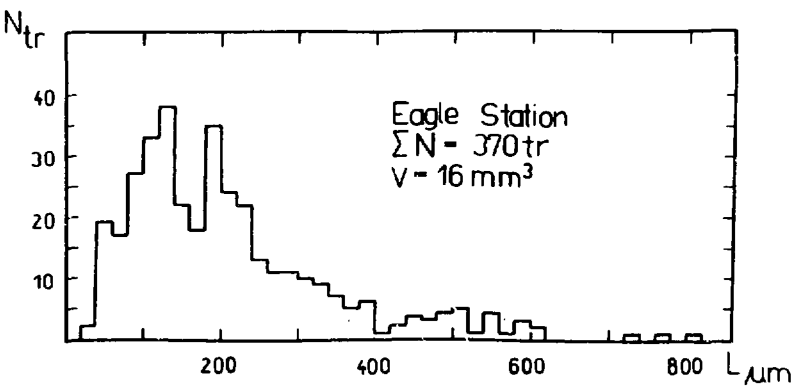
III. RESULTS AND DISCUSSION

Fig. 1 shows the length distribution of the 1905 tracks measured in 100 mm^3 of olivines from the surface parts of Marjalahti meteorite. The distribution of the lengths of the 370 tracks revealed in the 16 mm^3 volume of olivine from Eagle Station is presented in fig . 2. It should be noted that in the region of $L > 300\mu m$ about 50% of the tracks went beyond the crystal edges. As follows from figs. 1 and 2, the track length distributions of cosmic ray nuclei in olivines from Marjalahti and Eagle Station meteorites (having exposure ages of 175 and about 50×10^6 yr, respectively) have similar shapes. In order to increase the statistics for the heaviest component of the VVH nuclei we have examined an additional amount of 180 mm^3 of Marjalahti olivines with a track density of $4\text{-}5\times10^6$ per cm^2. In this case only the



N_{TR}
160
120
80
40
0
200
400
600
800
1000
$L_{\mu m}$
MARJALAHTI OLIVINES
VH track d. (4÷6)10^{6}cm^{-2}
ΣN=1906 V=100mm^3

Fig. 1



N_{tr}
40
30
20
10
200
400
600
800
$L_{\mu m}$
Eagle Station
ΣN - 370 tr
V - 16 mm^3

Fig. 2

tracks longer than 260μm were measured.
Fig. 3 shows the results of this examination together with all data obtained previously. It follows from fig. 3, the total Marjalahti olivine crystal volume examined amounts to 280 mm³ and the number of the measured tracks of L>260μm is 1564.

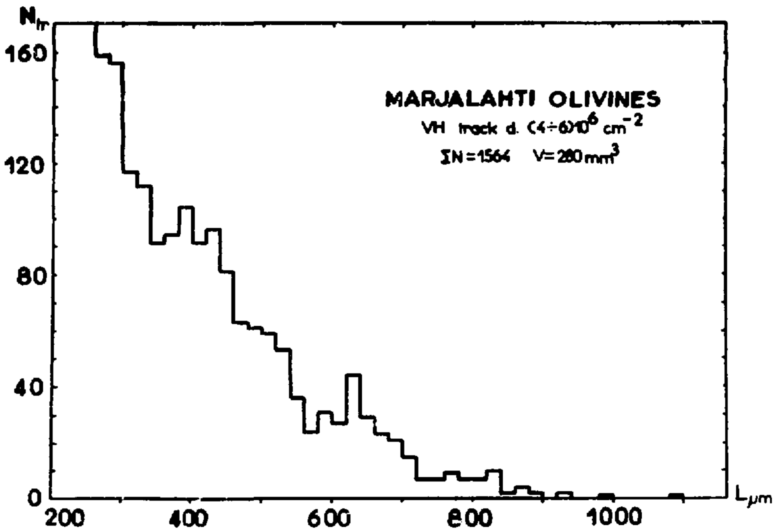


Fig. 3

The main difficulty in deciphering the measured spectra of the track lengths is the establishment of an unambiguous correspondence of the etchable track lengths to the atomic numbers Z of VVH nuclei. In ref./10/

two versions of deciphering track length spectra have been proposed. First, by a semiempirical extrapolation of the data on the etchable length of the tracks due to the accelerated nuclei ranging from Ti to Kr into the Z region of 92[4,9]. In this approximation (taking into account the partial facing of the tracks of VVH nuclei) the track lengths of $>560\mu m$ correspond to the region of $Z \geq 86$. The total number of such tracks is 275. If one takes into account the processes of slowing down and fragmentation in meteoritic matter, the abundance of the $Z \geq 86$ nuclei relative to the Fe nuclei is 9.7×10^{-7} which is in agreement with the data obtained by Fowler et al.[1,2].

According to another assumption[10] that only $720\mu m$ tracks are due to the U group nuclei one can compare the relative abundances of different groups of VVH nuclei and elements of the solar system[14]. The results of this analysis shown in table I indicate that the abundances of VVH nuclei and the elements of the solar system agree within a factor of 0.36-2.5. In terms of this extrapolation only one track longer than $1110\mu m$ (fig. 3) is due to a $Z>97$ nucleus (the low-energy portion of the track went beyond the crystal boundaries). The absence of tracks longer than 1.4 mm in the spectra shown in figs. 1-3 allows one to set the upper limit of the abundance of hypothetical superheavy elements ($Z \geq 110$) in galactic cosmic rays at 2.5×10^{-9} of that of the VH nuclei. Second, in agreement with ref.[10] it is possible to set the upper limit of the flux of magnetic monopoles of $g = n(137\ e/2)$ in the region of $n \geq 4$ at 3×10^{-19} cm^{-2} s sr.

TABLE I

The Abundance of Cosmic Ray Nuclei of Z>50

Charge groups	Track lengths, μm	Number of tracks	Abundance of cosmic ray nucl. $N_{Z,i}/20<Z<30$	Abundance in solar system/14/ $N_{Z,i}/20<Z<30$
$50<Z\leq 63$	140-260	889	0.8×10^{-5}	2.0×10^{-5}
$63<Z\leq 74$	260-420	1244	4.4×10^{-6}	2.0×10^{-6}
$74<Z\leq 84$	420-700	663	2.6×10^{-6}	8.7×10^{-6}
$90\leq Z\leq 96$	720-1000	58	1.9×10^{-7}	1.1×10^{-7}

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Received by Publishing Department
on May 17, 1977.