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NEUTRON FIELD OF THE EARTH, ORIGIN AND DYNAMICS

B.M.Kuzhevskij, O.Yu.Nechaev, M.I.Panasyuk, E.A.Sigaeva, N.N.Volodichev, and V.A.Zakharov

D.V.Skobeltsyn Institute of Nuclear Physics, M.V.Lomonosov Moscow State University

Abstract - It is shown, that both cosmic radiation (external source) and natural radioactive gases (inner source) are sources of neutrons near the Earth crust. Correlation between the Earth crust dynamics and variations of thermal and slow neutron flux near the Earth surface is studied. It is shown, that variations of neutron flux near the Earth crust can be used for short-term predicting of natural hazards.

INTRODUCTION

The Earth is rounded with neutron field, which is a flux of neutrons of different energies - from thermal energy up to billions eV. Energetic spectrum of neutrons, their distribution on altitude, latitude and longitude were studied in many experiments at sea level, in the mountains, by means of airplanes and baloons [1,2]. Fig.1 presents detailed vertical control traverse of thermal and slow neutrons' flux obtained in 1990 near Apatity, Kolsky peninsula [3].

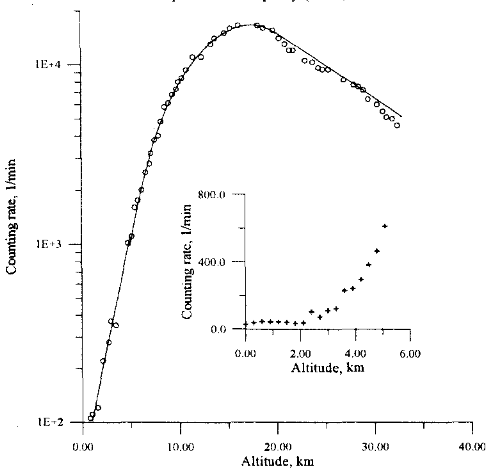

Fig. 1. Altitude dependence of neutrons' counting rate, obtained in the experiment, arranged in 1990 during flight of an aerostat over Apatity, Kol'sky peninsula [2]. Small circles indicate experimental data.

It is a well-known fact, that neutrons, observed near the Earth are originated from galactic cosmic rays, which produce them as a result of nuclear interaction with the Earth atmosphere and the Earth crust. High-energetic particles from solar flares also produce neutrons, but their contribution is occasional and can be easily separated. These neutron sources can be called external sources. But the Earth has another source of neutrons, which can be called its characteristic, or inner source of neutrons. This source is caused by presence of natural radioactive elements in the Earth crust [4].

ORIGIN OF THE INNER SOURCE OF NEUTRON FLUX NEAR THE EARTH SURFACE

First of all, the inner, or characteristic source of neutrons results from presence of natural radioactive gases, Radon isotopes in the Earth crust. In the radioactive family of Radon, Toron and Actinon there are isotopes, whose decomposition produces α-particles with energies from 5 up to 9 MeV. Neutrons are produced during interaction of such high-energetic α-particles with nuclei of the elements from the Earth atmosphere and the Earth crust. The primary energy of these neutrons is about 1 MeV.

Life span of such neutrons in the Earth atmosphere τ depends on time of thermolisation t and time of thermal neutron's capture by atmospheric nitrogen T.

$T = 1/nv\sigma$ = 0,06 second, where n - concentration of nitrogen nuclei, v = 2200 m/s - thermal neutron's velocity, α = 1,8 bn - cross section of thermal neutron's capture by nitrogen. Time of thermolisation can be found, using theory of neutrons propagation in the medium [5], from an equation $t = 1/\xi n \sigma v\{\ln E/E_{th}\}$, where E- neutron's primary energy, E_{th} - neutron's final energy, n - concentration of atoms in the air, σ = 10 bn - cross section of neutron's scattering in the air, ξ = 0,14 for air [2], v - mean velocity of neutron. It is the most uncertain quantity in the equation for t.

Calculation of energetic spectrum near the Earth surface [6] found out that over 70% of neutrons have energy lower 0.5 eV. If we take E = 0.5 eV, t = 0.12 s. So full life time of a neutron with primary energy about 1 MeV near the Earth surface is about 0.2 s. This process is a source of production of long-lived, radioactive isotope C^{14} and rare isotope N^{15} in the Earth atmosphere.

Contribution of the Earth inner source of neutrons can be determined by following method. If $N_\alpha(E)$ is concentration of α-particles with energy E in the atmosphere, then rate of neutrons' generation in the unit of volume Q_n can be found as following:

$$Q_n = \sum_{j,n} N_j N_\alpha(E) \sigma_{\alpha j}^n(E) v_{\alpha j} \quad (1)$$

where N_j - concentration of nuclei j in the air, $\sigma_{\alpha j}^n(E)$ - cross section of neutron's generation in interaction of α-particle with nucleus j, $v_{\alpha j}$ - relative velocity, which in fact coincides with v_α - velocity of α-particle. Summation is made by all types of nuclei in the air (oxygen, nitrogen, etc.), by all energies of generated neutrons and by all energies of α-particles.

Concentration of α-particles, which is produced by radioactive gases, can be found from the equation:

$$\frac{dN_\alpha}{dt} - \lambda_\alpha N_\alpha = Q_\alpha \quad (2)$$

where Q_α - rate of generation of α-particles in the unit of volume in radioactive decay, value $\lambda_\alpha = v_\alpha/R_\alpha$ defines the rate of α-particles'descent, v_α - velocity of α-particle, R_α - path of α-particle in the air. Solution of the equation (2) looks like:

$$N_\alpha(t) = \frac{Q_\alpha}{\lambda_\alpha}\left(1 - e^{-\lambda_\alpha t}\right)$$

For the stationary case, which we are interested in, we'll obtain:

$$N_\alpha = \frac{Q_\alpha}{\lambda_\alpha} = \frac{Q_\alpha R_\alpha}{v_\alpha} \quad (3)$$

Putting (3) into (1) we'll obtain rate of neutrons' generation:

$$Q_n = \sum_{j,n} N_j Q_\alpha R_\alpha \sigma_{\alpha j}^n \quad (4)$$

Then concentration of neutrons N_n is found from the equation:

$$N_n = \frac{Q_n}{\lambda_n} = Q_n \tau_n = \frac{\sum_{j,n} N_j Q_\alpha R_\alpha \sigma_{\alpha j}^n}{\lambda_n} \quad (5)$$

where τ_n - neutron's life span in the atmosphere, λn - rate of neutrons' descent in the atmosphere.

Using (4), (5) it is possible to study contribution of radioactive gases into production of concentration and flux of neutrons observed neat the Earth's surface.

DYNAMICS OF THE VARIATIONS OF NEUTRON FLUX NEAR THE EARTH SURFACE

As we see this contribution depends strongly on concentration of radioactive gases and conditions of their output into atmosphere. It also depends on elemental content of soil [6]. For different geographical points these quantities are essentially different. Comparison of experimentally observed fluxes at ground level in Moscow and Pamir shows, that contribution of inner neutron source can vary from several to thousands percents of the total neutron flux near the Earth crust (Fig.2).

Because, as we have already mentioned, contribution of inner neutron source is determined by concentration of radioactive gases and conditions of their output into atmosphere, it must be expected, that dynamics of the Earth crust will be indicated in variations of neutron flux near the Earth surface. In fact, dynamical processes of different nature in the Earth crust will result in disturbance of it's microstructure, and it in turn will result in changing of concentration of radioactive gases in the Earth crust and in changing of their output into the atmosphere.

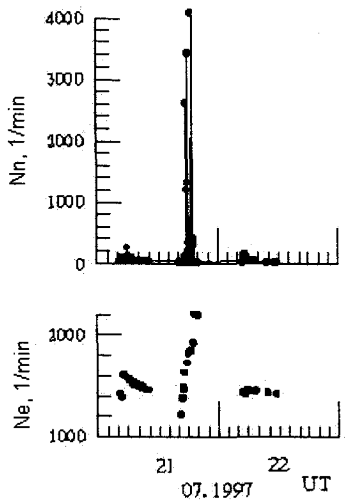

Fig. 2. The most strong neutron splash in the night of 21.07.1997 at Pamir at the altitude of 1100 m over sea level. 12-hour period of the splashes 21.07.1997 and 22.07.1997 correspond to the period of tidal waves.

The first indication of existence of relationship between dynamical processes in the Earth crust and variations of thermal and slow neutrons' flux near the Earth crust we have obtained during Pamir experiment. Thus strong and long increasing of thermal and slow neutrons' flux was observed during the full Sun eclipse 22.07.1990 [7]. By means of cadmium plate it was show that the basic flux of neutrons was directed from the Earth surface. This effect was explained in terms of described above theory. In this case concrete reason was related to gravity tidal wave, which increased during the Sun eclipse. Further regular Pamir observations found out that there are splashes in neutron flux, which correlate with full moons and new moons [7, 8]. It is presented at Fig.3 [7].

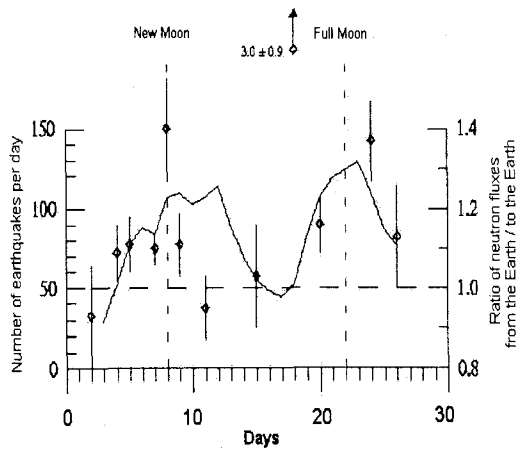

Fig. 3. Variations of neutron fluxes at Pamir (points) and number of earthquakes per day at the Pacific seismic ring (continuous line) during lunar month.

Relationship between gravity tidal wave and splashes in thermal and slow neutrons' flux near the Earth surface was also established during registration of neutrons in Moscow, Vorobjovy Gory. Experimental plant in Moscow works since 1992, and using the whole data array, we could show correlation between neutron splashes and phases of the Moon. Fig.4 presents the result of "epoch's method" application for this data array [6].

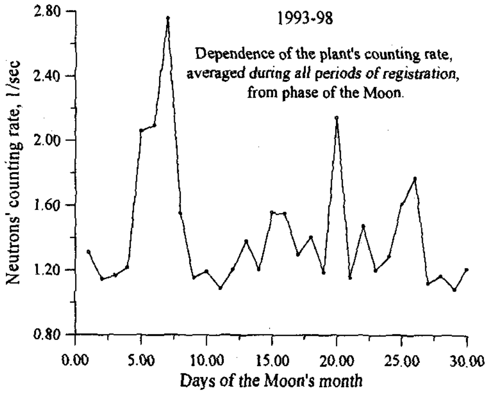

Fig. 4. Information from the Moscow experimental plant, distributed according the lunar month after application of "epochs' method". Full Moon is the 7th day of the lunar month.

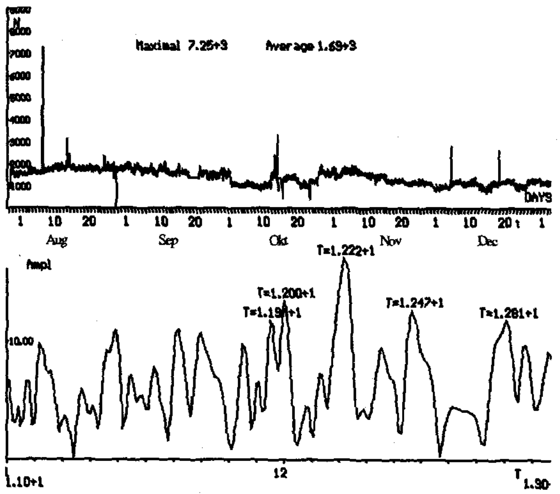

Fig. 5. Harmonic analysis of permanent neutron data array from the Moscow experimental plant (from 01.08.1998 up to 31.12.1998).

The Earth crust deformations, independent of its nature are studied with different geophysical devices and methods for many years. This study defined many periods (harmonics), which are results of gravitational interaction between the Earth, the Sun and the Moon [10]. These harmonics can be expected to appear in variations of neutron flux near the Earth crust. The result of harmonic analysis of permanent neutron data array in Moscow is presented at Fig.5 [11]. Here we can clearly see harmonics, correspondent with similar harmonics in gravimetry with accuracy of hundredth of hour. Of course, amplitudes of harmonics essentially differ, because relationship between dynamical processes in the Earth crust and variations of neutron flux near it is nonlinear.

On the strength of all told above about nature of inner source of neutrons near the Earth surface and about its contribution into the total flux of neutrons, it is expected, that neutron flux near the Earth surface is anisotropic. It is the more so, if we take into consideration, that the Earth crust, being a target for energetic cosmic particles, produces neutrons as a result of nuclear interactions with them. Such anisotropic flux must depend on season. Analysis of neutrons data for a long period simultaneously and separately from two directions (from upper and lower hemispheres) allowed not only to determine value of anisotropy of neutron flux near the Earth surface, but also to prove, that both sign and value of anisotropy depends on season. Fig.6 presents results of studies of seasonal dependence of neutron flux anisotropy according the measurements in Moscow, Vorobjovy Gory [12].

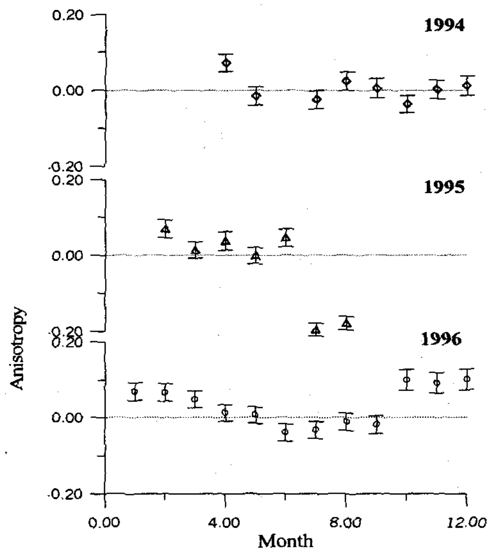

Fig. 6. Seasonal dependence of neutron fluxes' anisotropy according the data of the Moscow experimental plant.

CONCLUSIONS

So studies of neutron flux variations near the Earth crust result in establishment of the following facts:

1. The Earth crust is an separate source of thermal and slow neutrons.
2. Dynamical processes in the Earth crust result in variations of neutron flux near it.
3. Observation of neutron flux variations near the Earth crust can provide a basis for nuclear-physics monitoring of ecological condition of the Earth crust and lower atmosphere [13].
4. It is possible to develop a new, non-traditional approach to create a method for short-term predicting of natural catastrophes, such as earthquakes, volcano activity, tornado, etc. in terms of such nuclear-physics monitoring.

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