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Observation of thermal neutron flux variations connected with Lunar periods

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Abstract: Baksan Neutrino Observatory's results on variations of thermal neutron flux near the ground surface measured with an unshielded scintillator detector are presented. Experimental evidences were obtained of correlation between the long-term thermal neutron flux variations and lunar periods: Radon-due-neutron tidal waves. An evidence of a possible correlation between local seismic activity and thermal neutron flux has been established.

Introduction

Well-known radioactive noble gas Radon arises from decay chains of Uranium and Thorium (contained in terrestrial crust) and then diffuses into atmosphere. Simple but fruitful idea - to record a variation of Radon concentration in strained terrestrial crust as an indicator of local seismic activity - is used during long time by geophysical community amongst a lot of other factors preceding or accompanying an earthquakes. Information about concentration of Radon in atmosphere is also a matter of interest in some applied scientific programs such, for example, as environment monitoring in connection with influence of radioactive Radon on Earth's biosphere [1]. Commonly used devices for measurement of Radon concentration are based on recording of α-particles resulting from alpha decay processes of radon nuclei in air. We call it "standard method". There are well known discomforts in using this method, for example–humidity, atmospheric wind or ventilation of volume under control. But there is another possibility to trace Radon concentration, and directly in the crust. First it was assumed in work [2] that the terrestrial crust could be a possible source of neutrons, arising from (α, n)-reactions on the nuclei of crust elements after α-decays of Radon and Thoron (Rn220), then thermalizing inside and diffusing out of crust to the atmosphere. Hence, any variation of concentration of Radon and Thoron inside the crust will induce variation of neutron production, and that can be used for Radon concentration monitoring with some specific neutron detector. (Obviously, flux of neutrons recorded above the ground surface consists of at least two parts: a) ground neutrons and b) atmospheric neutrons which are sensitive to atmosphere parameters such as pressure and temperature.) Later in work [3] prominent correlation was noticed between *short-term increase* of thermal neutron flux, Moon phases and seismic activity. *Starting hypothesis* was the gravitational influence of Moon on variation of radon concentration in the crust. In above mentioned experiment [2,3] the *gas coronal counters* filled with ^{3}He were used to record thermal neutrons through the reaction: ^{3}He (n,p) ^{3}H + 765 KeV.

Detector of thermal neutrons

In our experiment we have used solid state detecting compound 6LiF+ZnS(Ag) to record thermal neutrons through the reaction 6Li (n, α) 3H + 4.78 MeV instead of standard method. Resulting α-particle and triton activate scintillator ZnS(Ag) viewed by photomultiplier. Output signals from PMT are put to a digital oscilloscope. Such recording methods guarantee more reliable set of data in comparison with a traditional gas counter and integral discriminator counting rate. The methods is both free from above mentioned demerits of standard method and also has an advantage in comparison with neutron monitors which are insensitive to outer thermal neutron flux due to polyethylene moderator shield. Scintillator area = 0.7 m2. Detection efficiency is equal to ~20%. Mean counting rate = 0.5 / sec. Detector is situated above the ground surface inside the experimental building at Baksan Neutrino Observatory, North Caucasus, 1700 meters a. s. l., 43o N, 43o E. It is worth while to note here that the detector was designed and constructed in 2001 to study hadron component of Extensive Air Showers. Original information about the detector and some results can be found elsewhere [4,5].

Data collection and analysis of meteo induced variations

In our report we pay attention only to variation aspect of Counting Rate of thermal neutron flux. A goal of our experiment was to detect possible correlation between variation of the flux and Moon periods and/or local seismic activity. Data set was accumulated during two periods:

1) 01, Dec, 2003–23, Jun, 2004. There was interruption from 19 Jan till 18 Feb, 30 days duration.
2) 19, Feb, 2006 – 25, Mar, 2007.

First results (with less amount of data then now) obtained with thermal neutron methods and also an estimation of the equilibrium thermal neutron flux from the crust were reported in [6]. Now the total amount of data is about 1.5 year. Effective live time is equal to 99 %. The counting rate (per 5 min) of digitised pulses inside a pre-set energy window was recorded along with atmospheric pressure and temperature in order to estimate the influence of atmospheric parameters on counting rate.

Usual barometric coefficient for neutrons generated in atmosphere = - 0.95 % / mm Hg. Simplest theoretical estimation of the temperature coefficient based on Maxwell neutron velocity distribution gives +0.5 % / % [6]. Multiple regression analysis of experimental data has been done in two ways: for day-after-day points and for mean day waves. For ≈ 400 day-after-day points result is : β = - 0.46 % / mm Hg, α = + 0.72% / deg. or ≈ 2% / %. For mean day waves result is : β = - 0.41 % / mm Hg, α = + 0.20 % / deg. or ≈0.56% / %.Our experimental barometric value is twice less than the standard value for atmospheric neutrons. This fact gives us a basement to assume that ≈ 50% of the recorded flux is of atmosphere origin while the rest being of soil origin. Comparison of the results of two approaches with theoretical values indicates an existence of noticeable self-determined seasonal wave of counting rate caused by snow and underground water level. It is known that Radon concentration has also seasonal waves. Further measurements are needed to make situation clearer.

Experimental Results.

Semi-diurnal and month periodicities

It is naturally to expect - following the *starting gravitational hypothesis* and the Radon-due-neutron production mechanism - existence of variations of thermal neutron flux from terrestrial crust. Hence, it was also naturally to apply a frequency analysis to accumulated data to search for some well-known periodicities arising from well developed theory of Moon-Earth-Sun dynamics. For example, generally known periodicity is tidal effect in ocean, which occur twice during a Moon-day period. Result of Fast Fourier Transformation (FFT) applied to sequence of one year (19/02/06 – 25/03/07) 5-min data set is shown in Fig.1. Horizontal axis is a frequency in 1/5min units. Vertical axis represents amplitude of corresponding semi-diurnal wave. With significance > 3 st. dev. we can recognize semi-diurnal periodicities: M2 = 12.384±0.007 hour, K2= 11.950±0.006 hour, S2 = 12.003±0.007 hour.

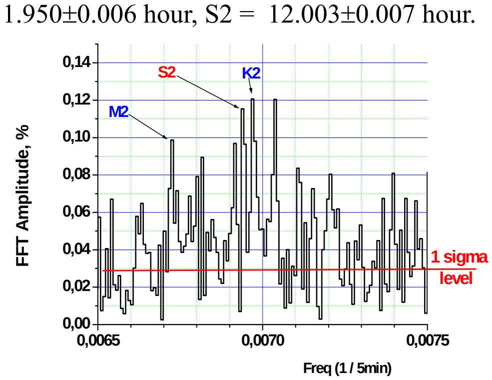

Figure 1: semi-diurnal periodicities

S2 is exactly a half of a solar day, while M2, K2 are different modes of second harmonics of Moon day. All prominent peaks are in good agreement with theoretical predictions. Then pressure and temperature data were analyzed in the same manner. Neither M2 not K2 modes were detected for atmosphere parameters. From the other side, more elaborate phase analysis is needed to ascribe the observed S2 mode to trivial solar-time second harmonics for meteo-factors. Now we may note that not meteo-corrected sequence of 5-min data was used.

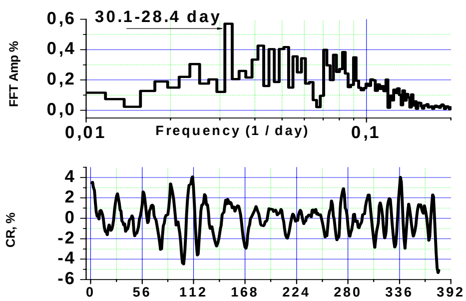

Figure 2: Moon month periodicity

Next step was a frequency analysis of day-after-day variations of counting rate. Now we do remind three most important - for that step of analysis - basic Moon month periods:

Anomalistic, $T_a = 27.554$ day, $\omega_a = 2\cdot\pi / T_a$

Draconic, $T_d = 27.212$ day, $\omega_d = 2\cdot\pi / T_d$

Synodic, $T_s = 29.531$ day, $\omega_s = 2\cdot\pi / T_s$

Meteo correction was done for the day-data set in formal way with day-after-day values of meteo coefficients, then 5-day smoothing procedure and finally high-pass filter (F_{cut}=0.01/day) were applied. Resulting curve for one year Counting Rate is shown in Fig.2b. In Fig.2a we show result of FFT applied to resulting curve 2b. Noticeable peak in 2a, though with bad resolution, arises at frequency corresponding to the range of Moon month periods. But even with the naked eye one can see obvious ≈ 28 day and ≈ 14 day (second harmonic) periodicities in the 2b curve behavior, clearly pronounced at the begin of year period, but with more complex structure at the end. Generally speaking there is nothing to wonder in such complex form of the observed curve taking into account that Moon's movement (hence, gravitational force) is treated in celestial mechanics as the most sophisticated one.

Now we suppose that observed semi-diurnal and month periodicities give us some basis to accept *starting gravitational hypothesis* as a working one for further investigations.

ADS model

An essence of model is an attempt of description of changing in time gravitational force in terms of amplitudes and phases of fixed basic periods of Moon rotation around Earth: Anomalistic, Draconic and Synodic. Hence we have tried to fit the observed day-after-day variations of counting rate by superposition of sinusoidal functionals corresponding to basic periods taking into account also second harmonics:

$$CR(t) \sim (1+A(t,\omega_a))\cdot(1+D(t,\omega_d))\cdot(1+S(t,\omega_d)) -1$$

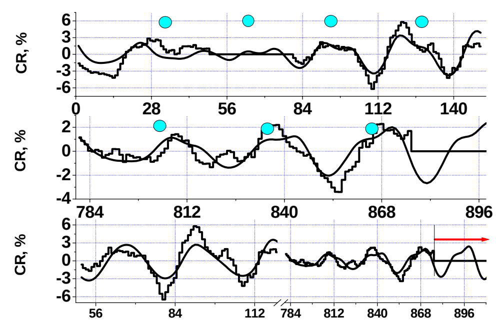

Figure 3: Comparison of experimental curve for Counting Rate with model fit

Amplitudes and phases in model are free parameters leading to max ratio R / χ^2 , where R – coefficient of correlation between experimental curve and model fit. A little bit more words about model one can find in [6]. In Fig.3 smooth curves show results of fitting procedure and step curves are experimental ones. Circles mark period of full Moon, what means that Moon-Earth-Sun system is aligned and gravitational tidal force reaches its maximum. Fig.3a is independent fit for 2003-04 yy, starting day is Dec, 01, 2003, R_a= +0.80. Fig.3b is independent fit for 2006 y, starting day is Jan, 01, 2004, R_b= +0.89.

Fig.3c is united fit for two periods separated with 1.5 year, R_c= +0.79. Large enough R-values make us free with inference that observed long-term variations might be in principle caused by gravitational tidal force.

Variation of flux vs seismic activity

There is widely spread opinion that tidal effect in terrestrial crust can be a trigger mechanism for earthquakes (EQs). Hence, if we adopt and combine together three premises, i. e. i) tidal effect arises variation of concentration of Radon in the crust, ii) Radon-due-neutrons flux does exist and iii) tidal trigger mechanism for EQs works, then ought to be correlation between thermal neutron flux and seismic activity. Fig.4 illustrates the claim. Panel (a) of the figure is simply fig.3a prolonged further. Panel (b) represents local North Caucasus seismic activity: vertical axis is sum of magnitudes of EQs(M>3.5) happened to be at the same day with distance < 250 Km from Baksan Neutrino Observatory. 2 days before a local burst of EQs on May 2 the flux started to increase, one day before it was 10% higher then expected from smooth behavior. On Feb 8 our detector was out of operation (see: Data collection...). Unfortunately (from the common sense point of view – just the opposite!) North Caucasus is not a region with high seismic activity. Also, second period of measurement (2006-07yy) was really seismic quiet one. By the way – one can compare amplitudes of variation

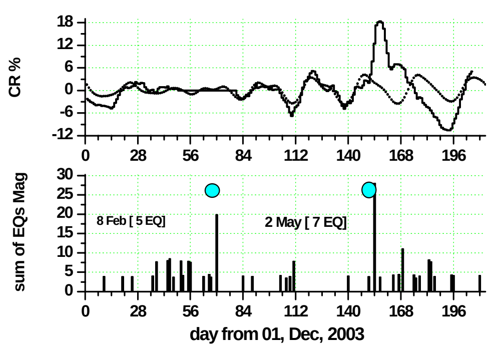

Figure 4: Abnormal behavior of neutron flux. Local seismic activity and full Moon.

for two periods: look at fig. 3c. Hence for a moment we have not enough observations to arrive at strict conclusion but we hope further and independent measurements with the methods will bring some additional information. Also we are of the opinion that only a net of such large-area detectors needs to be done to avoid spurious alarms.

Conclusion

1. A novel experimental approach to record variations of Radon concentration is presented. The methods is based on the recording of thermal neutron flux from the crust.
2. For the first time the experimental evidence of thermal neutron flux variations connected with Moon periods (*Radon-due-neutron tidal waves*) has been obtained.
3. The methods may be used in:
- applied geophysical researches as a part component of the seismic station net, for Radon-neutron monitoring of environment and of global Radon-neutron Earth's field.
- low background experiments.

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