Physics – Uspekhi **63** (3) 309 – 310 (2020)

PACS number: **01.90.+g**

Physics news on the Internet (based on electronic preprints)

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DOI: https://doi.org/10.3367/UFNe.2020.02.038723

1. Geoneutrino

The Borexino collaboration, in which Russian scientists are taking part, has presented [1] the results of 12 years of measurements of the geoneutrino — the antineutrino $\bar{\nu}$ generated inside Earth upon the fission of radioactive element nuclei and perhaps other processes. The possibility of recording geoneutrinos was pointed out by G A Gamow as far back as 1953. In 1960, M A Markov suggested that the reactions of inverse beta-decay should be used for their registration, and they were first registered in 2016 using Borexino and KamLAND detectors. The Cherenkov Borexino detector is located in a mountain tunnel at Gran Sasso National Laboratory in Italy [2–4]. The analysis of the spectra of geoneutrinos and the background from reactor neutrinos gives the total number of registered geoneutrinos (~ 53). After subtracting events from Earth's crust, the number of $\bar{\nu}$ from the mantel is $23.7^{+10.7}_{-10.1}$. Radioactive decays are accompanied by heat release. This allows the total radiogenic heat release of the lithosphere — ($38.2^{+13.6}_{-12.7}$ T W) to be found from the geoneutrino flux, which is highly consistent with the silicate models of Earth's structure. The neutrinos interact weakly and leave freely the center of Earth. Therefore, their observation provides unique insight into the processes inside the planet. According to one of these hypotheses, a natural nuclear reactor may function inside Earth's core. The observed geoneutrino flux puts a restriction on its possible power: $W < 2.4$ T W.

2. Deformation of atomic nuclei

Many atomic nuclei can be deformed and take different shapes [5]. However, in all hitherto known cases, deformed nuclei could be either only symmetric about the mirror reflection in the equatorial plane or only asymmetric (e.g., pear-shaped). Yu Ts Oganessyan (JINR, Russia) and colleagues from China and the USA have discovered that one and the same atomic nucleus can take both symmetric and asymmetric shapes. Gamma-ray photons emitted upon spontaneous ^{252}Cf nucleus fission were registered at the Berkeley National Laboratory (USA). Intranuclear transition energies in a daughter ^{144}Ba nucleus were measured and a layout of energy level positions was constructed. Six levels and several transitions between levels were revealed for the first time. The shape of the nuclei can be reconstructed using this information. It turns out that the ^{144}Ba nucleus can be deformed as an octupole asymmetrically shaped about spatial reflection, but it can also have a quadrupole symmetric shape.

3. Quantum correlations of a massive mirror

In 1967, V B Braginskii obtained the limit on the precision of measurements known as the Standard Quantum Limit conditioned by the noises and by the backreaction effect of measurement on the system [6]. This limit was already surpassed earlier in micromechanical experiments at cryogenic temperatures with the help of quantum nondestructive measurements. LIGO/Virgo laser interferometers register gravitational waves from the merging of black holes and neutron stars. H Yu (LIGO collaboration) and co-authors have shown [7] that the LIGO detector is also able to surpass the standard quantum limit. The interferometer operated in the normal mode as in gravitational wave registration, except that light with a high degree of quantum compression was used. It was established that the detector produced quantum correlation between the position of the 40-kg quartz mirror and 200-kW laser beam fluctuations, which allowed nondestructive quantum measurements of 3 dB (a factor of 1.4) below the standard quantum limit. Impressive is the fact that quantum fluctuations of light affect the motion of such a massive mirror, and this influence can be measured even at room temperature.

4. Electrically pumped topological laser

Topological lasers with valley edge electromagnetic modes used to generate lasing are of great interest for technical applications owing to their high generation stability. The topological lasers created earlier were pumped using radiation from another laser. Y Zeng (Nanyang Technological University, Singapore) and colleagues have demonstrated for the first time an electrically pumped terahertz topological laser [8]. According to its principle of operation, it is a to quantum-cascade laser. Electrically generated lasing occurs in a photon crystal consisting of an array of quasi-hexagonal holes (triangles with cut angles) in flat semiconductor layers. Standing waves do not occur in such a crystal, but an electromagnetic field circulates along the perimeter of triangles, and valley edge modes are excited. As a result, the radiation spectrum consists of several regularly positioned peaks near the frequency of 3.2 THz. The insertion of artificial defects into the photon crystal did not have a substantial effect on laser operation.

Uspekhi Fizicheskikh Nauk **190** (3) 336 (2020)
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5. Periodic fast radio burst

Although more than a hundred cosmic fast radio bursts (FRB) have already been discovered, the mechanism of their generation has not yet been reliably established [9]. According to one of the hypotheses, bursts occur on magnetized neutron stars — magnetars. The CHIME/FRB collaboration discovered [10] the periodicity of fast radio bursts which, perhaps, will help to clarify their nature. The FRB source 180916.J0158 + 65 was observed for 400 days. All 28 bursts recorded within this time were found to get into phase windows four days wide and positioned with a period of 16.35 ± 0.18 days. Although no bursts occurred in half of these intervals, and from 1 to 5 bursts were noticed in other intervals, the above-mentioned periodicity of the phase windows have a statistical significance of $\sim 5\sigma$. The reason still remains unknown. The period of ~ 16 days is likely to correspond to the orbital period of neutron star motion around the companion star along an elongated orbit. It has not been ruled out that the periodicity is explained by eclipses or lensing by the other star or by the accretion disc. In the magnetar model, periodicity may be explained by a slow neutron star's rotation.

6. Possible identification of high-energy neutrino sources

Cosmic neutrinos ν with energies > 50 TeV are registered by the IceCube detector located in the Antarctic ice [11, 12]. The origin of these ν is not yet known. Only once has a neutrino event possibly coincided with a gamma-ray burst on a blasar — an active galactic nucleus. A V Plavin (Astro Space Center of the Lebedev Physical Institute of the Russian Academy of Science — ASC of LPI RAS, Moscow Institute of Physics and Technology — MIPT), Yu Yu Kovalev (ASC of LPI RAS, MIPT, and Max Planck Institute for Radio Astronomy), Yu A Kovalev (ASC of LPI RAS), and S V Troitskii (Instute for Nuclear Research of RAS) have reported the discovery [13] of a correlation between the neutrino events and galactic activity in the radio frequency band, which may testify to the origin of high-energy neutrinos in radio-bright galaxies. The observational data of 3388 galaxies by the RATAN-600 radio telescope and very-long-baseline radio interferometers, as well as the IceCube data on 56 neutrino events with energies above 200 TeV, were used. Radio galaxies located in the direction of the ν arrival were revealed to exhibit a heightened activity, with a probability of random coincidence of $\sim 0.2\%$. Moreover, the ν recording time often gets into the period of galactic activity growth. Possibly, ν are produced in the scattering of high-energy protons by photons emitted by the accretion disc around the central black hole or by other protons in a nearly pc-sized region. Radio emission may have been generated in farther jet regions.

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