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1. Extension of neutrino wave packet

It is difficult to detect neutrinos because of the small interaction cross section, but this circumstance allows neutrinos to retain quantum coherence for a long time — until the wave packets corresponding to different mass states spatially diverge, which must be accompanied by a decoherence and damping of neutrino oscillations [1]. Hence, the question of the wave packet size is of importance for neutrino physics. Only weak constraints (> 21 pm) on the neutrino wave packet were obtained earlier in reactor neutrino experiments. J. Smolsky (Colorado School of Mines, USA) and his co-authors have obtained a new direct constraint [2]. Their experimental installation included ^{7}Be nuclei intercalated in the upper layer of tantalum film of a single superconducting tunnel transition, which was used as a high-energy-resolution (~ 1 eV) sensor. At a temperature of 0.1 K, four peaks, corresponding to e^- capture with K- and L-shells, were observed, and the energy width of the daughter recoil nucleus, emitted under the radioactive ^{7}Be decay, was measured. This resulted in obtaining a constraint from below on the wave packet size — 6.2 pm (three orders of magnitude more than the nucleus size). Some of the anomalies observed in reactor neutrino experiments have earlier been explained by the small size of the neutrino wave packet, but the new constraint practically rules out this hypothesis.

2. Traveling along a closed timelike curve

In the General Relativity Theory, there formally exist mathematical solutions, including closed timelike curves along which objects can travel into their past. Examples are the blackhole metric with angular momentum and the Gödel metric (rotating universe). However, it was believed that logical contradictions should arise in flying along a timelike loop — time-travel paradoxes. L. Gavassino (Vanderbilt University, USA) has performed a new analysis of this problem in an axially symmetric Gödel-type universe from the viewpoint of standard quantum mechanics [3]. It was shown that a system moving along a closed timelike loop undergoes a spontaneous quantum discretization and during the flight the entropy time arrow reverses. The entropy eventually decreases to its initial value, and the system goes back to its initial state. This implies, for example, that the memories of an observer inside a spaceship moving along a timelike loop will necessarily be erased by the end of the trip. This conception is close to the 'self-consistency principle' proposed by I.D. Novikov (ASC LPI). Thus, in the quantum case, one can avoid logical contradictions concerning motions along closed timelike lines.

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3. Two-photon Landau–Zener–Stückelberg–Majorana (LZSM) tunneling

Weak nonperturbative quantum-mechanical effects beyond the main order are typically hardly accessible for theoretical analysis because the perturbation theory cannot be applied. One such effect is the LZSM tunneling observed in some phenomena in solid state physics and in other physical situations. I. Bjorkman, M. Kuzmanovic, and G.S. Paraoanu (Aalto University, Finland) have analyzed two-photon LZSM tunneling in a weakly anharmonic transmon qubit [4]. Observation of higher-order effects in this system is possible, because first-order processes prove to be very weak. Transition from the ground state of the qubit to the second, bypassing the first, excited state, is realized with the help of a two-photon phase-modulated pulse. A 98% level population transfer took place. The advantage of this approach consists in high stability of quantum transitions, which is of importance for control over quantum-dynamical processes.

4. High-energy neutrinos

The KM3NeT neutrino telescope located in the Mediterranean Sea registered exceptionally high-energy neutrinos whose source is probably a blazar — a galaxy with an active nucleus and a jet directed almost exactly towards us [5]. The interaction of neutrinos near underwater detectors give birth to muons generating charged particle cascades, and Vavilov-Cherenkov radiation takes place. A muon with an energy of 120^{+110}_{-60} PeV, flying almost horizontally, was revealed in the event of February 13, 2023, which received the number KM3-230213A, and the energy of ~ 220 PeV of the corresponding neutrino was 30 times higher than the maximum energy registered in the IceCube experiment. The neutrino energy spectrum falls rapidly and, therefore, the KM3-230213A neutrino highly likely appeared through another mechanism than a lower-energy neutrino. Twelve blazars exist within the KM3-230213A localization region. Transient events may serve as an indication of a particular neutrino source, and some IceCube events have already been found to relate to radio bursts on blazars [6, 7]. The radio telescope RATAN-600, operating at SAO RAS, also registered a flare on the blazar PMN J0606-0724 located in the direction of the neutrino event KM3-230213A, and the flare maximum coincided in time with the arrival of a neutrino, the probability of chance coincidence being equal to 0.26% [8].

Thus, this blazar is a probable neutrino source. The cosmogenic neutrinos predicted by V.S. Berezinsky and G.T. Zatsepin in 1969 also remain a possible explanation for KM3-230213A. These neutrinos are born in the interaction of super-high-energy cosmic rays with background photons.

5. Supermassive black hole (SMBH) in Large Magellanic Cloud (LMC)

Some stars in the halo of our Galaxy move at high velocities (> 1000 km s^{-1}) along trajectories that take them into the intergalactic space. One way of superfast star origination is the J. Hills mechanism: capture of one of the stars of an SMBH binary system and a high-speed ejection of the second star. Based on Hubble and Gaia data, J.J. Han (Harvard-Smithsonian Center for Astrophysics, USA) et al. have performed a new calculation of the trajectories of high-speed stars of spectral class B to show that the most probable place of ejection of half of the stars is not the Galactic center, but the LMC [9]. Moreover, the SMBBH mass in the LMC, responsible for star ejection, makes up $\sim 6 \times 10^5 M_{\odot}$, which is almost an order of magnitude less than the SMBH mass in the Galactic center. This model also reproduces well the observed clustering of high-velocity stars in the constellation Leo due to the presence of an additional velocity boost as the LMS moves around the Galaxy.

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