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1. η' mesons in atomic ^{12}C nuclei

Theoretical calculations predict the existence of unstable meson nuclei that captured additional mesons in their composition. In the new experiment, performed in the Helmholtz Center for Heavy Ion Research GSI (Germany), ^{12}C ions were irradiated by protons with energy of 2.5 GeV, the deuterons, that flow out of the nuclei near the threshold of production of η' mesons in the composition of the multiplet of pseudoscalar mesons were registered, and the spectrum of fragments from the decay of nuclei was measured [1]. The results of the experiment confirmed the existence of ^{12}C nuclei with η' mesons in bound states with reliability of $\simeq 3.5\sigma$, the η' mass inside the nuclei decreasing by $\simeq 61$ MeV due to the interaction with nuclear matter, which is in good agreement with the theoretical calculations.

2. Indefinite causal ordering in quantum mechanics

As distinct from classical physics, where causally associated events are time ordered, quantum mechanics admits an Indefinite Causal Order and even a superposition of the order of such events. This unexpected fact was confirmed in experiments with quantum switches, using a fully or partially device-dependent method (for a specific device implementation). An uncertain order does not, however, imply a backward time influence. C.M.D. Richter (Vienna Center for Quantum Science and Technology VCQ, Austria) and their co-authors demonstrated this effect for the first time by a device-independent method based on verification of the inequality essentially analogous to Bell's inequalities [2–4] but adapted for fixation of the indefinite causal order [5]. The experiment used a photon quantum switch in a Mach–Zehnder interferometer configuration. This inequality is violated at the 18σ level, providing the absence of causal ordering and corresponding hidden variables. The experiment currently contains so-called 'loopholes' similar to those found in the verification of Bell inequality violation, which could be closed in future experiments. The effect of indefinite causal ordering is of interest both for fundamental physics and for possible practical applications in quantum technologies.

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3. Gyroscopic effect in a nonrotating ferromagnet

F. Ahrens and A. Vinante (the Institute of Photonics and Nanotechnology IFN-CNR and the Bruno Kessler Research Organization, Italy) were the first to discover the gyroscopic effect in a nonrotating solid ferromagnetic sample [6]. A microsphere 40 to 60 μm in diameter, made of ferromagnetic Nd–Pr–Fe–Co–B alloy levitated in the magnetic field of a superconducting trap at a temperature of 4.18 K. Small magnetic field variations due to sphere rotations in two directions were measured using two loops connected to SQUIDs. The direction of the sphere magnetic moment underwent small vibrations (libration) along an elliptical trajectory. The modes of these vibrations were interrelated by the law of conservation of the total angular momentum with allowance for the internal spin momentum of electrons, while earlier such a hydromagnetic bond was only observed in rotating samples. This effect can find application in the design of ultrasensitive magnetometers and for quantum stabilization.

4. Skin layer in water

Previously, in experiments on stimulated Raman scattering of laser radiation on vibrations of OH valence bands in water, a response was recorded at the characteristic frequency of ice (~ 3200 cm^{-1}) in the envelope of OH band, indicating the formation of water layer with an icelike structure. However, the question of thickness of the water layer in which this response is formed and its properties remained open. In the new experiment by S.M. Pershin (A.M. Prokhorov General Physics Institute RAS) and his colleagues from GPI RAS and the HSE, the laser beam was focused under the water meniscus surface and continuously shifted downwards [7]. A deformation was found of the OH band of spontaneous Raman scattering because of the increasing contribution of the ~ 3200 cm^{-1} component indicating a spontaneous formation of icelike structures in a 1- to 3-mm layer at room temperature. Moreover, independent studies of this layer in glass capillaries revealed an increase of up to 25% in the meniscus lift height proportional to the increase in surface tension. The authors believe that this effect is due to the hydrogen bonds between water in the layer with new properties and SiO_2 molecules in the capillary walls. These experiments demonstrate that even in simple distilled water nontrivial, previously unknown anomalies and spontaneous processes of formation and evolution of its surface layer can occur over a period of approximately three hours.

5. Testing General Relativity (GR)

Although GR has so far successfully passed all the tests, deviations from the predictions of this theory with increasing precision of experiments and observations cannot be excluded, and several possible GR modifications have already been proposed. The LIGO/Virgo/KAGRA collaboration presented new results of GR testing using the data from the gravitational wave detectors that record mergers of compact objects — black holes and neutron stars [8]. Along with the previous data, the characteristics of 42 new events from the observation session O4a were used. Deviations from General Relativity might be expected both in the properties of the compact object merger events themselves and in the character of gravitational wave propagation from sources to detectors. The performed 19 tests are divided into three categories: self-consistency of the observed effects, possible deviations from GR in favor of modified theories, as well as the properties of the black holes formed during mergers. Studied in the latter case were, in particular, quasi-normal oscillation modes at the ringdown stage with allowance for the Kerr metric effects. No deviations from the GR predictions were detected in these studies, and new stronger constraints were obtained on a number of parameters describing possible deviations. It is of importance that some of the tests verify GR in the dynamic nonlinear strong-field regime realized during the merger of compact objects.

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