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Yu N Eroshenko

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1. Possible discovery of a glueball

The theory of strong interactions in quantum chromodynamics predicts the existence of an exotic hadron: a glueball differing from ordinary mesons and baryons by the absence of quarks in its composition. Such particles, consisting of gluons alone (carriers of strong interaction), can be born owing to a nonlinear self-interaction of the gluon field carrying a color charge. They cannot be reliably registered in experiment because of their short lifetime and glueball mixing with mesons, although some evidence of glueball production was obtained at the Large Hadron Collider in 2021. The radiative decay of the J/ψ meson is a process rich in gluons and is therefore thought of as promising for glueball investigation. The hadron X(2370), also known as $\pi^+\pi^-\eta'$ resonance, which may be the lightest pseudoscalar glueball, must be present among the decay products. The probabilities of different J/ψ-meson decay channels, as well as the mass and width of X(2370) decay, were measured anew in the BESIII experiment at the Beijing electron–positron collider [1]. The statistical significance of X(2370) recording, based on the analysis of 10^{10} J/ψ decays, is estimated to be 11.7σ. Moreover, the spin parity of this particle was measured for the first time and was 0^{+-}, as it should be for a glueball. The measured mass of $2395 \pm 11(\text{stat.})^{+26}_{-94}(\text{syst.})$ MeV of particle X(2370) is also quite consistent with the mass 2395 ± 14 MeV predicted for the glueball by the 'lattice QCD' method.

2. Quantum measurement without wave function collapse

In quantum mechanics, the measurement process is often described as a wave function collapse, when in the interaction with a classical measuring device the quantum system passes into one of the proper states [2–4]. Nevertheless, H E Dyte (University of Sheffield, Great Britain) and his co-authors have demonstrated in their experiment an example of quantum measurement without a wave function collapse [5]. Investigated was a qubit on the basis of electron spin at the quantum dot GaAs/AlGaAs in a magnetic field. With the help of coupling far from resonance, the qubit interacted with a system of $\sim 10^4 - 10^5$ nuclear spins with a long coherence time. Owing to such a large number of spins, the system could be considered to be a classical object. The state of the electron spin was copied straight away onto states of many nuclear spins, and this redundancy allowed measuring the electron state with a quantum fidelity of 99.85%, the measurement not leading to a wave function collapse, but allowing a description of the measuring process within its linear evolution. Measurement without a wave function collapse resembles the 'quantum Darwinism' concept describing the transition from a quantum to a classical state.

Yu N Eroshenko Institute for Nuclear Research,
Russian Academy of Sciences,
prosp. 60-letiya Oktyabrya 7a, 117312 Moscow, Russian Federation
E-mail: erosh@ufn.ru

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3. Nonstationary Kapitza–Dirac effect

In 1933, P L Kapitza and P Dirac showed a theoretical possibility of electron beam diffraction of a standing electromagnetic wave due to stimulated Compton scattering [6]. The Kapitza–Dirac effect has been investigated experimentally since 1965 [7, 8], but it was only in 2001 that it was observed in pure form with a verification of Bragg's condition of reflection from a standing wave. Initially, the Kapitza–Dirac effect was considered in the stationary case with a monochromatic electron spectrum. R Dorner (Goethe University, Germany) and his colleagues have become the first to observe a nonstationary ultrafast Kapitza–Dirac effect for short electron pulses with a broad spectrum [9]. The electrons got out upon xenon atom tunnel ionization [10] under 60-femtosecond laser bursts. Part of the laser light, which did not produce ionization, was a test beam on which interference took place as a gain of additional oscillations in the pulse distribution of electrons. The spectral shifts were inversely proportional to the time delay between electrons and the test laser pulse. Calculations showed that this is just the dependence to appear due to the Kapitza–Dirac effect.

4. Ultrafast optical microscopy beyond diffraction limit

The application in optical observations of evanescent fields made it possible to overcome the diffraction limit, but for slow processes only. On the other hand, the use of ultrashort optical pulses allows observation of fast processes, but with poor spatial resolution — much larger than the atom size. T Siday (University of Regensburg, Germany) et al. have developed a combined technique, for the first time achieving in one optical observation a subdiffraction resolution on the scale of one atom and time resolution at the level of one oscillation of an electromagnetic wave [11]. A tungsten needle was used near the surface of a WSe_2 monolayer on a gold substrate illuminated by light pulses. Under the influence of light, electrons tunneled between the needle and the surface at the light wave frequency, and electromagnetic radiation of the tunneling current was observed. The spatial resolution in observation of surface defects using this method made up $\sim$pm with a time resolution of $\sim$fs. For the use of metalenses for obtaining images with subwave resolution, see [12].

5. Radiation near a black hole

An accretion gas disc, which has a high temperature and emits X-rays, is formed, as a rule, around black holes (BHs). The disc has an inner boundary near the last stable orbit. The emission of radiation by matter in the space between the BH horizon and the inner boundary of the disc was typically neglected, assuming the disc to end abruptly. However, as far back as 1973, I D Novikov and K Thorne noted that the magnetic field can modify this boundary condition and, according to the results of modern numerical simulation, radiation from the indicated internal region can make a noticeable contribution to the general flux. In a series of studies, A Mummery and S Balbus formed an analytical model allowing a description of radiation generation in the internal region. In their new work, A Mummery (University of Oxford, Great Britain) and his co-authors [13] have used the new model to fit a BH spectrum in the X-ray binary system MAXIJ1820 + 070, consisting of a star and a BH with a mass of $(7-8)M_{\odot}$. Data from the NuSTAR and NICER space telescopes were used. The radiation component, generated between the last stable orbit and the BH horizon, has been reliably revealed for the first time. At 6–10 keV, such a component is dominant, and the shape of the radiation spectrum cannot be reproduced without taking it into account. The obtained parameter of the angular momentum of the BH turned out to be rather small: $a_* < 0.5$. This investigation confirms the behavior of matter near a BH, predicted by the General Theory of Relativity.

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