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Yu N Eroshenko

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1. Proton polarizability

One of the enigmas in elementary particle physics is the problem of proton electric polarizability α_E determined by the complicated quark-gluon interaction. According to theoretical calculations, α_E must decrease monotonically with increasing transferred momentum squared. In measurements, however, a local maximum was discovered near $Q^2 = 0.33$ GeV^2, and the existence of this anomaly could be neither confirmed nor refuted for two decades. In a new independent experiment [1], carried out at T Jefferson National Laboratory (USA), the maximum has been revealed with a still higher fidelity than before. The measurement accuracy was increased by studying excited intermediate states of the proton, measuring the azimuthal asymmetry of scattering, and investigating $ep \to ep\pi^0$ reactions simultaneously with $ep \to ep\gamma$. An electron beam with an energy of 4.56 GeV met liquid hydrogen, the $ep \to ep\gamma$ reaction products were registered, and the cross section of virtual Compton scattering containing information on polarizability was measured. The found position of the local maximum of α_E coincides with that obtained in previous measurements, but the maximum turned out to be a little lower. The characteristic radius of proton electric polarizability greatly exceeds the charge radius [2]. Thus, the presence of an anomaly in α_E has been confirmed, although the available theories fail to present an explanation. The above-mentioned problem is planned to be solved in the near future through new calculations using the 'lattice QCD' method at high computational capacities and in new experiments.

2. Mechanism of superconductivity in $Bi_2Sr_2CaCu_2O_{8+x}$

In 1934, H Kramers predicted the possibility of so-called superexchange interaction of electrons and, in 1950, F Anderson improved this model. It was hypothesized that this mechanism can be responsible for electron pairing in some superconductors (cuprates), where superexchange is due to quantum tunneling (virtual jumps) of electrons between copper atoms in neighboring atomic layers through intermediate oxygen atoms. In particular, this can occur in $Bi_2Sr_2CaCu_2O_{8+x}$, a compound that becomes a high-temperature hole-doped superconductor. Using a modified superconducting-needle tunnel microscope, S M O'Mahony (National University of Ireland in Cork) and his co-authors have studied the relation between the charge exchange energy (the value of the energy barrier) and the electron pair density in hole-doped $Bi_2Sr_2CaCu_2O_{8+x}$ [3]. The obtained dependences suggest that the superexchange interaction is the cause of electron paring in $Bi_2Sr_2CaCu_2O_{8+x}$.

3. Light amplification in a topological waveguide

Topological photon devices based on the properties of radiation edge modes can find important applications, including the topological quantum generation of light, in topological lasers, and photon routing. B-U Sohn (Singapore University of Technology and Design) and their co-authors have worked out and demonstrated experimentally a new device, namely, a topological nonlinear parametric amplifier [4]. Its work is described by the topological Su–Schrieffer–Heeger model. The device consists of 199 parallel film waveguides with a total width of 0.6 μm, of which 9 play the role of domain wall localizing edge modes of transmitted radiation. Parametric amplification of a signal (up to 12.8 dB) propagating together with pumping radiation is due to the nonlinearity of silicon nitride enriched in silicon, of which the waveguides are fabricated. This waveguide maintains a data transmission rate of 54 Gbit s^{-1} and can achieve nonlinear wavelength conversion.

4. Laboratory modeling of earthquakes

The problem of earthquake prognosis is rather topical, but earthquake shock mechanisms are highly unclear [5–7]. Along with full-scale observations and mathematical simulations, laboratory modeling is also important. S B L Cebry (Cornell University, USA) and her co-authors investigated quartz powder under pressure between immobile and moving polymer blocks serving as a model of tectonic plates [8]. In the powder, a creeping front propagated, from time to time inducing abrupt skipping (earthquakes) transforming into complex successions of aftershocks in which a great role was played by the prehistory of these events. The obtained results may possibly provide insight into some processes in real earthquakes. Solving the complicated problem of predicting earthquakes may require allowance for a whole array of factors, such as electromagnetic perturbations in the atmosphere, and aerosol and radon ejections.

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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5. Local cosmological expansion?

Although gravitationally bound systems, in particular, galaxies and binary stars, do not expand with the surrounding Universe, cosmological effects can still affect their inner dynamics at a very low level. This effect is due to the boundary conditions in the region of matching the expanding cosmological reference frame with the local rigid reference frame [9] and also due to dark energy gravitation. In observations of the motion of the binary pulsars PSR B1534 + 12 and PSR B1913 + 16 at 2.5σ, corrections were previously revealed, which may correspond to the effect of local cosmological expansion. K Agatsuma (University of Birmingham, Great Britain) has discovered its signatures in two more systems [10]. In the pair of a pulsar and the white dwarf PSR J1012-5307, the emission of gravitational waves leading to orbit compression is compensated by the effect of local cosmological expansion, and therefore the orbital motion almost exactly obeys the Keplerian law. The second system is the binary pulsar PSR J1906 + 0746. As a result, the total statistical significance increased to 3.6σ, although the level of 5σ has not yet been attained.

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