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1. Existence of the 4-quark particle Z(4430)$^-$ is confirmed

The birth of particle Z(4430)$^-$ consisting of four quarks $c\bar{c}\,d\bar{u}$ was first evidenced by the Belle Collaboration at KEK accelerator (Tsukuba, Japan) in 2008. In the LHCb experiment at the Large Hadron Collider, its existence has been confirmed at the 13.9σ confidence level. 25176 $\pm$ 174 decays of B^0 mesons born in pp collisions were examined: $B^0 \to \psi'\pi^- K^+$, $\psi' \to \mu^+\mu^-$. The decay product distributions measured over the invariant mass were modelled with allowance for the known resonant K^* states. The K^* states alone turned out to be insufficient for data reproduction, and an additional highly significant component was needed, corresponding to a short-lived particle-resonance Z(4430)$^-$ with a mass of nearly 4430 MeV, a resonance width of ≈ 172 MeV, a negative unit charge, and spin-parity $J^P = 1^+$. Also measured were the interference properties in the resonance region and the loop in the Argand diagram. At the present time, several particles are already known which can comprise four quarks, but it is only for Z(4430)$^-$ that the LHCb experiment showed reliably that this particle belongs to particles-resonances. The nature of the Z(4430)$^-$ particle has not yet been clarified in full, for it can be either a tetraquark or a coupled two-meson system.

Source: *Phys. Rev. Lett.* **112** 222002 (2014)
http://arXiv.org/abs/1404.1903

2. Verification of the equivalence principle using a neutrino

The observed effect of neutrino oscillations testifies to the fact that the flavor states of neutrinos are a superposition of the mass states but are not coincident with them. The question arises as to whether the interaction of each of the mass states with the gravitational field has the same form as that of nonoscillating particles, i.e., whether the equivalence principle holds true for mass states. A Esmaili (G V Wataghin Institute of Physics, Brazil) and his colleagues studied this problem on the basis of data on atmospheric high-energy ($E_\nu = 20$ GeV – 400 TeV) neutrinos registered in the IceCube experiment being carried out in the Antarctic ice. Violation of the equivalence principle would cause an additional phase shift between the states inducing oscillations. Although no such additional oscillations were revealed, constraints were obtained on the products of the gravitational potential ϕ and the differences of parameters γ_i defined as factors in the gravitational interaction of mass states. If the equivalence principle is valid, then γ_i is equal to unity for $i = 1, 2, 3$. It was found that $|\phi(\gamma_2 - \gamma_1)| < 9.1 \times 10^{-27}$ and $|\phi(\gamma_3 - \gamma_1)| \leqslant 6 \times 10^{-27}$. These constraints are, respectively, by ~ 4 and ~ 1 order of magnitude more rigorous than those obtained from other experiments. Thus, at today's level of accuracy, the IceCube data confirm the equivalence principle for neutrino mass states.

Source: http://arXiv.org/abs/1404.3608

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3. Quantum entanglement of three photons

C Erven (University of Waterloo, Canada) and his colleagues have demonstrated the quantum entanglement effect of three distant photons when the measurement events related to their states are separated by a space-like interval and, therefore, could not exhibit a causal link. In earlier experiments, this condition was only met for two particles. Three photons in spin-entangled states were obtained by the method of parametric down-conversion and mixing. Two photons flew toward detectors at distances from 700 to 800 m, while the optical path of the third photon was localized near the source. The detectors responded at random instants of time determined by a random-signal quantum generator located at a distance of 446 m from the source of photons. The states of the three photons were measured within the time interval in which the photons were unable to exchange signals propagating with the speed of light. Violation of Mermin's inequalities, an analogue of the Bell inequalities but applied to three particles, was investigated. These inequalities were violated at the 9σ level, which testified with high confidence to quantum entanglement of three photons. The results of the experiment both serve as verification of the fundamental bases of quantum mechanics and can find practical application in quantum cryptography and quantum communications.

Source: *Nature Photonics* **8** 292 (2014)
http://arXiv.org/abs/1309.1379

4. Berry's phase in a semiconductor

If the conductivity of a substance possesses nontrivial topological properties, the electron wave functions may experience an additional phase shift (may have Berry's phase) upon almost periodic changes in the states of the system. Berry's phase has been observed in experiments with the quantum Hall effect and topological insulators. The new observation of Berry's phase, this time in a BiTeI semiconductor with properties described by a Hamiltonian with the spin-orbit interaction in the Rashba form, was performed by H Murakawa (RIKEN Center for Emergent Matter Science, Japan) and his colleagues. The conductivity of thin BiTeI layers in a magnetic field was measured at a temperature of 1.8 K. Two groups of oscillations corresponding to two spin states were revealed. Berry's phase for the inner Fermi surface (in a weak external magnetic field B) was observed from oscillations of the second derivative of conductivity, $-d^2\rho_{xx}/dB^2$. And Berry's phase for the outer Fermi surface (for high B) was revealed from Shubnikov–de Haas oscillations, which were observed up to $B = 56$ T. The systematic phase shift of oscillations measured in experiment agrees with the theoretical predictions of the presence of Berry's phase in the BiTeI semiconductor.

Source: *Science* **342** 1490 (2014)
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5. RadioAstron examination of interstellar plasma

The 10-meter orbital radio telescope RadioAstron and two ground-based telescopes (Arecibo and Westerbork Synthesis Radio Telescope) have been combined to observe radio pulses of pulsar PSR B0950 + 08 at a wavelength of 92 cm in the ground–space interferometer mode and to receive information on the line-of-sight distribution of interstellar plasma which scatters the radio signal and causes its scintillations. The space and ground-based telescopes combine into an interferometer with a 220,000 km baseline, providing a record angular resolution at meter wavelengths. The expected signal characteristics were calculated by T V Smirnova and V I Shishov as far back as 2008, and the results were confirmed with a good accuracy in these observations. The signal scintillations had the form of modulation at a level of $\approx 40\,\%$ with frequencies much lower than the carrier frequency. Such modulation could be caused by plasma configuration at the line of sight in the form of two scattering layers and a 'cosmic prism' — a rather sharp plasma distribution gradient declining the radio emission through the angles of 1.1–4.4 angular milliseconds. The far scattering layer lies most likely at the external boundary of the local bubble (the rarified gas region inside the galactic arm) at a distance of 26–170 pc, and the near layer (4.4–16.4 pc) lies on the ionized surface of the molecular cloud. The spectrum of turbulent density fluctuations in both layers follows a power law with exponents $\gamma_1 = \gamma_2 = 3.00 \pm 0.08$, which differs from the Kolmogorov spectrum with $\gamma = 11/3$. Most of these results could not be obtained by observations from Earth's surface only, because, under pulsar radiation refraction, the Fresnel zone exceeds Earth's diameter. The RadioAstron was launched into orbit in 2011 aboard the Spectrum-R space observatory. This project is being implemented by the Astro Space Center of the Lebedev Physical Institute and the Lavochkin Research and Production Association with the participation of some other Russian and international organizations.

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