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# Physics news on the Internet (based on electronic preprints)

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## 1. Test of electric charge conservation

The law of electric charge conservation is a fundamental physical principle and has been checked in many physical experiments. Nevertheless, it cannot be ruled out that in some very rare processes the electric charge is not conserved. In the Borexino experiment at Gran Sasso National Laboratory (Italy), whose main goal is solar neutrino registration, a search was implemented for possible charge nonconservation due to the decay of electrons into neutrinos and photons, $e^- \to \gamma + \nu_e$, in atoms of a liquid organic scintillator. The 256-keV gamma rays emitted in the decays might interact with the electrons in the scintillator substance and cause light flashes registered by photomultipliers. According to the data accumulated over 408 days, no $e^-$ decays were registered within the accessible accuracy, but the absence of observed events yielded a new time limitation of $> 6.6 \times 10^{28}$ years on the $e^-$ lifetime in the $e^- \to \gamma + \nu_e$ process. This limitation is two orders of magnitude better than that obtained in the 1998 experiment which preceded Borexino. For the check of the electric charge conservation, see also the paper by L B Okun' in *Usp. Fiz. Nauk* **158** 293 (1989) [*Sov. Phys. Usp.* **32** 543 (1989)].

Source: *Phys. Rev. Lett.* **115** 231802 (2015)
http://arXiv.org/abs/1509.01223

## 2. Gamma-ray spectroscopy of ${}^4_\Lambda$He nuclei

Charge symmetry stating that strong interaction in atomic nuclei does not depend on the nucleon charge is of paramount importance for the properties of many nuclei but refers to an approximate symmetry. The experimentally measured difference between the binding energies of ${}^3$H and ${}^3$He nuclei caused by charge symmetry breaking agrees well with the results of computations. However, in the case of supernuclei ${}^4_\Lambda$He and ${}^4_\Lambda$H with $\Lambda$ hyperons in their composition, the experiment gives thrice as large a value as that predicted theoretically. To find out the statistical significance of this difference, new experiments were needed. J-PARC E13-1$^{st}$ collaboration used the gamma-ray spectroscopic method to examine $1^+ \to 0^+$ transitions between the levels of ${}^4_\Lambda$He nuclei produced in ${}^4\mathrm{He}(\mathrm{K}^-, \pi^-){}^4_\Lambda\mathrm{He}$ reactions. The effect of charge symmetry breaking turned out to depend substantially on spins, being rather large for the state $0^+$ and small for $1^+$. A comparison of the energy difference $1406 \pm 2(\mathrm{stat.}) \pm 2(\mathrm{syst.})$ keV of levels $1^+$ and $0^+$ in the ${}^4_\Lambda$He nucleus obtained in these experiments with analogous measurements carried out earlier for ${}^4_\Lambda$H confirmed the discrepancy between the experimental data and the available theoretical predictions.

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## 3. Low-voltage tunnel field-effect transistor

The limit has now been reached when a further miniaturization of ordinary field-effect transistors is obstructed because of the worsening of their characteristics. Moreover, the operating voltage of the transistor cannot be lowered by diminishing its size. The development of transistors operating on new principles, for example, using the quantum tunneling effect seems promising. D Sarkar (University of California, Santa Barbara, USA) and colleagues have fabricated a tunnel field-effect transistor with an operating voltage of 0.1 V and the mean value of the inverse logarithmic steepness of 31.1 mV per decade during the channel current variation by four orders of magnitude at room temperature, the minimum value being only 3.9 mV per decade. This result was attained by creating a channel of $MoS_2$ in the form of a bilayer 1.3 nm thick on a doped germanium layer serving as the source. The heterostructures obtained have the thinnest tunnel gap and a large tunneling-contact area. The transistor operates through quantum tunneling of electrons from the valence band of germanium to the $MoS_2$ conduction band. The control voltage applied to the gate causes a relative shift of these bands and, accordingly, the tunnel current changes. The transistor was fabricated using the methods of electron-beam lithography and gas-phase chemical deposition. Graphene-based tunnel field-effect transistors were designed earlier, but they did not have the above-mentioned band-to-band tunneling, for which reason the inverse logarithmic steepness below 60 mV per decade could not be obtained. The energy dissipation in the new transistor is 90% lower than that of conventional transistors, which makes the new technology fairly economical and promising for application in microelectronics.

Source: *Nature* **526** 91 (2015)
http://dx.doi.org/10.1038/nature15387

## 4. Vortices in a granular medium

G Combe (3SR Laboratory, Grenoble, France) and colleagues have analyzed the statistical properties of granular-medium particles to establish that in some cases the velocity fluctuations of particles in the medium are vortex-like and resemble turbulent vortices in fluids. A quasi-two-dimensional array of wooden discs from 3 to 30 mm in diameter placed between two transparent plates was chosen as the medium investigated. A spatial redistribution of discs under the effect of rising pressure upon external compression of the medium was examined by a photographic survey. Along with observation of vortices, confirmed for the first time was the dependence $\alpha = 2/(3-q)$ between the value of the exponent $\alpha$ in the law of particle's displacement in the medium, $\langle x^2 \rangle \propto t^\alpha$, and the value of $q$ characterizing the statistical particle distribution, which was predicted by C Tsallis and D J Bukman. A transition from an anomalous diffusion regime to a Brownian behavior was also evinced.

Source: *Phys. Rev. Lett.* **115** 238301 (2015)
http://dx.doi.org/10.1103/PhysRevLett.115.238301

## 5. Magnetic structures in the vicinity of a supermassive black hole in the center of the Galaxy

M D Johnson (Harvard-Smithsonian Center for Astrophysics, USA) and colleagues have used the prototype of the 'Event Horizon Telescope' to reveal partially ordered magnetic structures near the event horizon in a Galactic Center supermassive black hole, Sagittarius A*. The Event Horizon Telescope is a system of radio telescopes situated on different continents of the Earth and operating as a single radio interferometer with a superlong base. The described observations were conducted at the 1.3-millimeter wavelength by four telescopes of the system, and by 2020 their number is planned to reach 13. Spatially resolved were the regions of polarized emission on scales of about 40 ang. μs, which corresponds to about six black-hole gravitational radii. The presence of such regions is indicative of the existence on this scale of a spatially ordered magnetic field in which the observed radio emission is generated by electrons via the synchrotron mechanism, the emission characteristics corresponding to the magnitude of the magnetic field of several dozen gausses. Variability of the radio signal on time intervals of less than an hour was also detected. An ordered magnetic field in the interior of the accretion disc might be due to its extension to a toroidal configuration or, in another model, due to magnetic flux accumulation near the event horizon.

Source: *Science* **350** 1242 (2015)
http://arXiv.org/abs/1512.01220

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