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Physics news on the Internet (based on electronic preprints)

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1. Observation of atmospheric neutrinos in the IceCube

The IceCube experiment (Collaboration) conducted at the South Pole by an International team of 276 researchers (M G Aartsen et al.) has measured the flux of atmospheric electron neutrinos ν_e (cumulatively with $\bar{\nu}_e$) in the energy range from approximately 80 GeV to 6 TeV. These neutrinos are created in decays of muons and K mesons which are produced in the terrestrial atmosphere exposed to cosmic rays. The spectrum of atmospheric neutrinos ν_μ has been measured up to 400 TeV, whereas the spectrum of ν_e has so far been measured only up to energies of tens of GeV, and only upper bounds were available in higher-energy ranges. According to the data gathered over the first year of observations with the DeepCore detectors incorporated in the IceCube experimental facility in the Antarctic ice at a depth of 2100 m, 1029 candidate events were identified after the initial selection applying a number of criteria. The remaining background is mostly produced by atmospheric μ and ν_μ. The excess of ν_e over the background was found to be $496 \pm 66\,(\text{stat.}) \pm 88\,(\text{syst.})$, which agrees well with the values obtained in calculations of interactions between cosmic rays and the terrestrial atmosphere.

Source: *Phys. Rev. Lett.* **110** 151105 (2013)
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2. Quantum correlations

Even when violations of Bell inequalities were experimentally detected, three logical possibilities (loopholes) remained of adding hidden parameters (local realism) to quantum mechanics. Two of them (the locality problem and the problem of free choice) were successfully eliminated in earlier experiments with photons. Finally, A Zeilinger and his colleagues (Institute of Quantum Optics and Quantum Information of the AstrAcSci and the University of Vienna, Austria) have succeeded in eliminating in a pioneering experiment with entangled photons the third logical loophole that follows from the problem of incomplete (unfair) sampling. This problem stems from the fact that the experiment fails to collect all particles of EPR pairs. It can be assumed, though, that violation of Bell inequalities characterizes only the recorded sample, while the entire ensemble of particles obeys the theory with hidden parameters. Collection efficiency could be improved and the loophole thus eliminated by technical improvements in the desigh of the photon sources and detectors. The source of EPR pairs of photons operated by a mechanism of parametric conversion in nonlinear crystal, and a transition-edge sensor was utilized as a high-efficiency detector; its output signal was processed by a superconducting amplifier. The violation of Bell's inequalities was studied in the Eberhard form for photon polarizations. The violation of inequalities and, correspondingly, the validity of predictions of standard quantum mechanics was recorded at the 69σ confidence level. At the moment, therefore, the three logical loopholes for local realism have been eliminated in three different experiments with photons. The next step of principal importance could be the elimination of all three loopholes within a single experiment, and their elimination for other particles.

Source: *Nature*, online publication of April 14, 2013
http://dx.doi.org/10.1038/nature12012

3. Properties of three-layer carbon nanotubes

The interaction between the outer layer of carbon atoms in coaxial double-layer carbon nanotubes and the environment substantially modifies the characteristics of interaction between the layers. However, if a triple-layer nanotube is synthesized, its outer layer should serve as a sort of protective screen for the two inner layers. In an experiment by T C Hirschmann (Massachusetts Institute of Technology, USA), the outer two layers were grown simultaneously applying a technology that allowed growing large-diameter nanotubes. The inner space of the grown double-layer nanotube was then filled with fullerenes; as a result of half an hour of heating up to 2000 °C, the fullerenes were transformed in 45% of the cases into a single inner nanotube. Five different triple-layer nanotubes were synthesized in this manner and investigated; each exhibited its own combination of semiconductor and metallic properties. It was then established, by applying the Raman spectrum technique, that the distance separating the two inner layers varied from 0.323 to 0.337 nm. Various phonon oscillating modes were investigated; the most important of these were the radial modes. The properties of multilayer nanotubes are of great interest for designing nanostructures with unique properties.

Source: *ACS Nano* **7** 2381 (2013)
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4. Coherence evolution in polariton condensate

V V Belykh (Lebedev Physical Institute of the Russian Academy of Sciences, Moscow) and his colleagues have studied the expansion of a coherence area in the polariton system in a GaAs microresonator. The excitation of polaritons and the subsequent formation of Bose–Einstein condensate were caused by irradiation with picosecond laser pulses at a temperature of 10 K. The experiment for studying the expansion of spatial coherence through the condensate used the Young two-slit geometry: the light emitted by polaritons through the slits produced an interference pattern observed for different distances between the two slits, and the dynamics of the interference pattern were investigated employing a streak camera with 3 ps resolution. Measure-

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ments showed that the coherence area expanded at a velocity of 0.6×10^8 cm s^{-1}. The transition to the condensate state occurred in several stages (as was established already in the theoretical papers by Yu M Kagan, B V Svistunov, and G V Shlyapnikov), the most important of which is the relaxation to the state of lowest energy, in which the kinetic energy of particles is on the order of magnitude of the interaction energy between the particles. The velocity of expansion of coherence in similar experiments with atomic gases was found to reach a mere 0.1 mm s^{-1}. The factor causing this huge difference is due to a much shorter characteristic time of relaxation in the gas of polaritons.

Source: *Phys. Rev. Lett.* **110** 137402 (2013)
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5. Results of observations by the Planck telescope

Data have been given on the anisotropy of the cosmic microwave background (CMB) radiation in the range of $\sim 25-1000$ GHz, obtained with the NASA's Planck space telescope over the first 15.5 months of observation. In many respects, these data are the most accurate and the most complete available today. Using them, it has proved possible to improve the values of the key cosmological parameters; in some cases, the new values differ significantly from the data surveyed by other telescopes (WMAP, etc.). Thus, the new Planck-provided data considered together with some other observations indicate that the baryon matter component in the Universe comes to approximately 4.8% of the total density, dark matter to about 25.8% (the pre-Planck estimate for this quantity was 22.7%), and dark energy to about 69.2%, while the adjusted Hubble constant now equals $H_0 = 67.8$ km s Mpc^{-1}. No contribution of non-Gaussian or entropic perturbations was detected at the achieved level of accuracy. The measured exponent of density spectrum perturbations was $n_s = 0.9608 \pm 0.0054$. The Planck telescope also measured, with high confidence at the 25σ level, no gravitational lensing effect for cosmic microwave background radiation, caused by large-scale structures. The team will also publish later, as data processing continues, polarization-related data. The data confirm the presence of earlier-reported large cold spots in the radiation distribution. The statistical confidence of another anomaly — that of global anisotropy — remains low, and the results collected by the Planck telescope completely satisfy the Standard Cosmological ΛCDM model.

Source: http://arXiv.org/abs/1303.5062

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