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Physics news on the Internet (based on electronic preprints)

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1. Neutrino oscillations in T2K experiment

The first events of transformation (oscillations) of muon neutrinos into electron neutrinos in the T2K experiment (Japan) were recorded in 2011 by comparing the composition of a beam of muon neutrinos close to its emergence point from the Tokai accelerator and at a distance of 295 km in the Super-Kamiokande detector. To date, 28 events have already been observed, with a recording confidence of the oscillations having reached 7.5σ. It is important that T2K is an 'appearance' type of experiment for beam neutrinos. As a rule, experiments identifying the appearance of particles are more unequivocal than those associated with their 'disappearance', in which a particle deficit is declared. $\nu_\mu \to \nu_e$ oscillations are closely related to violation of the *CP*-invariance in weak interactions, and it is expected that, as statistical data keep accumulating, it will be possible to study *CP*-violation in the lepton sector by tapping neutrino oscillations. Several events of a different type of oscillations ($\nu_\mu \to \nu_\tau$) have been observed recently in the OPERA experiment (Italy). Some Russian researchers are taking active part in both the T2K and the OPERA Collaborations.

Source: http://t2k-experiment.org/2013/07/new-results-from-t2k-conclusively-show-muon-neutrinos-transform-to-electron-neutrinos/

2. Photon analogue of Schrödinger's cat

A I Lvovsky (University of Calgary, Calgary, Canada and the Russian Quantum Center at Skolkovo, Moscow) and his colleagues have succeeded in generating experimentally an entangled state of a single photon and a macroscopic ensemble of more than 10^8 photons — that is, they created a photon analogue of Schrödinger's cat. The quantum entanglement between the micro- and macroobjects has already been implemented in a number of systems, such as atomic ensembles; however, it has been generated for the first time in the case of photon systems. The experiment started with a pair of photons in entangled states generated by creating parametric down-conversion. One of the photons of the pair was then subjected to multiple amplification by shifting in the phase space. The measurements were carried out using quantum tomography, while the inverse shifting made it possible to check that quantum coherence had actually taken place. Owing to the quantum entanglement, the state of a single photon affected the state of the large photon system, which could be resided in a superposition of states which would differ by tens of thousands in the number of photons.

Source: *Nature Physics*, imline publication dated 21 July 2013 http://dx.doi.org/10.1038/nphys2682

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3. Controlled skyrmions

Skyrmions constitute stable spin textures that carry a topological charge; they were theoretically predicted in 1961 in T Skyrme's field model and by now have been observed already in several distinct systems. N Romming and his colleagues at the Institute of Applied Physics, University of Hamburg in Germany have succeeded for the first time in selectively creating or annihilating individual skyrmions with local spin-polarized currents from a scanning tunneling microscope on ultrathin magnetic films composed of a PdFe bilayer on the surface of an iridium crystal. Metastable topological configurations, close in energy but separated by an energy barrier were observed in the vicinity of the external magnetic field 1–1.4 T. The potential of the tunnel microscope (on the order of 0.1–1 V) caused reversible transitions across the barrier between energy levels and, correspondingly, the creation or annihilation of individual magnetic skyrmions. The reversibility of transitions signifies that in this mode skyrmions can be readily controlled in order to record and store information. In this manner, several skyrmions have been created successively and independently at a local spot of the film, after which they also appear to have been destroyed one at a time. Skyrmions were registered on the basis of characteristic features of changes in the current through the tunnel. Each skyrmion in whose region the magnetic moment completed 1 full revolution covered roughly 270 surface atoms of the film. The experiment was carried out at a low temperature ($\leqslant 8$ K) when the probability of transitions between topological states due to thermal fluctuations was low. The promise of practical applications of skyrmions is based, among other things, on their magnetic state being more stable than in ordinary magnetic domains.

Source: *Science* **341** 636 (2013) http://dx.doi.org/10.1126/science.1240573

4. Rotational Doppler effect

Researchers at the Universities of Glasgow and Strathclyde (Glasgow, Great Britain) have succeeded for the first time in measuring the rate of angular rotation of bodies on the basis of their interaction with a light beam whose photons possess orbital angular momentum. If the angular size of the rotating body is small, the ordinary Doppler effect required to measure the velocities of parts of the body is weak, so that the Doppler effect for the measurement of body's parts becomes inapplicable; however, 'twisted' light is quite suitable for this purpose. What is created in the beam reflected from the rotating body is a shift in frequency proportional to the product of the body rotation frequency and orbital angular momentum of the photons. In the experiment conducted by M P J Lavery et al., a rotating piece of aluminium foil was irradiated by two beams of a semiconductor laser with angular momenta $\pm 18\hbar$, equal in magnitude but oppositely directed, and created by programmed space modulators. The rotation axis was parallel

to the line of sight but reflection, in fact, occurred at certain small angles because of some unevenness of the surface. As could be expected, the reflected light in the two beams attained frequency shifts of opposite signs — red and blue shifts. The experiment recorded beats created in the interference of these beams, so the rate of rotation of the disc could be calculated from the characteristics of beating. The results obtained at different rotation speeds were found to be in agreement with the theoretical calculations of this particular effect.

Source: *Science* **341** 537 (2013)
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5. *B*-mode of polarization of cosmic microwave background

For the first time, the *B*-mode of polarization of the cosmic microwave background (CMB) radiation, connected to the vortex component of the polarization tensor, has been detected using a 10-m South Pole Radio Telescope located in Antarctica at the South Pole. The CMB polarization component can be generated by its scattering on nonuniformities of plasma and matrix (gravity waves) in the recombination epoch, or as a result of gravitational lensing of radiation in cosmological nonuniformities of density. The vortex-free *E*-mode was already observed by the DASI interferometer telescope in 2002. These new data obtained during the first season of working with polarization-sensitive bolometric detectors of the South Pole Telescope reliably demonstrated for the first time the presence of the *B*-mode. The calculation of 4-point correlation functions for $l \geqslant 150$ multipoles showed that the measured *B*-mode correlates at the 7.7σ confidence level with the matter distribution map obtained in the Hershel IR scan, as well as with *E*-mode measurements. As we know from other observations, IR surveys give a reliable representation of the gravitational potential, which is in fact responsible for gravitational lensing and for the transformation of the *E*-mode to the *B*-mode of polarization occurring in the process. Very important information can be obtained in the future about the early stages of evolution of the Universe, including the inflation stage, upon registration of the polarization of CMB caused by relic gravitational waves. The data obtained with South Pole Telescope comprise the background against which a search for polarization signals due to gravitational waves could be carried out.

Source: http://arXiv.org/abs/1307.5830

Compiled by *Yu N Eroshenko*
(e-mail: erosh@ufn.ru)